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Investor ambiguity, systemic banking risk and economic activity: The case of too-big-to-fail

Tarik Driouchi, Raymond HY So and Lenos Trigeorgis

Abstract: This paper examines the relationship between investors' ambiguity in the financial options market and systemic banks' risk. Eliciting ambiguity information from option pricing data on the twelve major U.S. banks between 2003 and 2010, we show that higher behavioral deviations from risk-neutral and Bayesian valuation (i.e., investor ambiguity) are associated with higher systemic banks' downside, market and credit risks. Consistent with behavioral explanations, we confirm the detrimental effect of ambiguity on financial market outcomes and find strong evidence of ambiguity among call and put option holders. Variance decomposition indicates that such a pattern of behavior explains a significant proportion of U.S. banking risk variance. This effect is more pronounced during periods of economic turbulence and bank stress (i.e., the 2007-2009 crisis), and holds after controlling for size, tail risk, implied volatility, and volatility of volatility dynamics. We also document that ambiguity from the financial market has a depressing impact on real economic activity, including capacity utilization, non-farm payrolls and overall economic performance. Our findings are robust to alternative specifications of ambiguity such as multiple priors and expected utilities with uncertain probabilities.

Key words: behavioral theory, ambiguity, derivatives, too-big-to-fail, systemic risk

1. Introduction

Rarely has the classical distinction between risk and uncertainty (e.g., Knight, 1921; Keynes, 1921) been so evident in the financial markets than in the years surrounding the most recent global financial crisis. The banking crisis of 2007-2008 and its aftermath exposed the fragility of standard frameworks used to monitor risk and instability in the financial system (Poon, 2009; Stiglitz, 2011; Brown and Hao, 2012). These developments have turned global stock exchanges into occasional silos of fear and ambiguity. As a result, a number of authors and policy makers have called for stricter market regulation and closer scrutiny of investment behavior during economic cycles (Vinogradov, 2012; Wegener et al., 2019; Cumming et al., 2018).

While various studies in mainstream finance and economics have attempted to provide behavioral explanations to specific market phenomena especially in the context of financial crises or highly uncertain events (Low, 2004; Poteshman, 2006), fewer empirical papers have explicitly analyzed the presence or impact of ambiguity - as uncertainty beyond risk - in financial decision-making and financial markets (e.g., Shu, 2010; Boyarchenko, 2012; Driouchi et al., 2018). In organizations research, however, and due to fundamental insights from behavioral decision theory (Cyert and March, 1963; March, 1978; Einhorn and Hogarth, 1985), notions of ambiguity and Knightian uncertainty have been investigated relatively extensively in several empirical contexts (individuals and corporate). These include leadership and management quality (Jacquart and Antonakis, 2015), entrepreneurship and venture capital (Sommer et al., 2009; Petkova et al., 2014; Artinger and Powell, 2016), acquisition integration (Cording et al., 2008), research and development (Carson et al., 2006), individual assessment (Dunning et al., 1989), cash management and derivatives use (Friberg and Seiler, 2017), and financial reporting and IPO listing (Arnold et al., 2010; Park and Patel, 2015). Park and Patel (2015), in particular, document a positive relationship between ambiguity inferred from the IPO prospectuses of newly listed U.S. firms and their IPO underpricing, confirming that ambiguity matters to prospective investors. Similar conclusions are reached by Arnold et al. (2010) who link ambiguity information to IPO excess returns. Friberg and Seiler (2017) show that higher ambiguity (risk), inferred from 10-Ks, is associated with higher cash holdings (derivatives use). Despite this recent evidence, no study we know of has empirically examined how or whether investor ambiguity affects the performance of banks, the financial system and real economic activity. We contribute to the literature by unveiling the role of investors' ambiguity (inferred from systemic banks' financial option pricing data, and for robustness, from the iShares US financials ETF (IYF)) in the financial system and the real economy. We add to extant research by examining the case of too-big-to-fail banks and investigating linkages between investor subjective behavior, derivatives markets, systemic risk and real economic outcomes.

This is important given contemporary rhetoric on the role of banks and derivatives instruments in recent financial crises (Boyarchenko, 2012; Bruce and Skovoroda, 2013; Ivanov et al., 2016; Bushman et al., 2018), and growing evidence on the antecedents and implications of deviating behavior and cognition in financial services (e.g., Vaaler and McNamara, 2004; Easley and O'Hara, 2009; Bilinski et al., 2019). The case of U.S. systemic banks and their exposure to uncertainty during the 2003-2009 period indeed provides a unique natural setting for testing ambiguity theory predictions in practice. We address the following questions: *does investors' ambiguity behavior in the financial options market contribute to systemic banking risk? Is this effect more pronounced during banking crises and what are the implications for the real economy?* Specifically, we investigate whether and the extent to which investors' ambiguity in the banking options market is associated with systemic banks' risk and banking instability in the equity and credit markets, and - subsequently - the real economy.

Drawing from behavioral theory, our paper primarily studies the ambiguity of investors holding call and put options on U.S. systemic bank stocks over the seven-year period 2003-2009. We define ambiguity as uncertainty beyond probabilistic risk, namely: investors' subjective deviations from risk-neutral valuation and Bayesian behavior (see Abdellaoui et al., 2011; Baillon and L'Haridon, 2016). We study ambiguity under Choquet utility (CU), α-multiple priors (α-MEP) and the expected utility with uncertain probabilities (EUUP) (Chateauneuf et al., 2001;

Ghirardato et al., 2004; Izhakian and Yermack, 2017). We posit that banking investors' ambiguity in the option market results in errors in judgment, subjective valuation, suboptimal exercise decisions, ineffective hedging and poor trading performance in the marketplace (see e.g., Easley and O'Hara, 2010; Leiblein et al., 2017 on the role of subjective uncertainty and cognition in financial trading and resource allocation processes), increasing risk and instability in the financial system. We view ambiguity in our context as the subjective deviations from risk-neutrality (Bayesian behavior) caused by uncertainty in model specification and in the number of distributions characterizing cognitive valuation processes (e.g., see Mosakowski, 1997; Einhorn and Hogarth, 1986). Thus, we examine the relationship between investors' ambiguity and systemic banks' overall market performance. The first part of our sample covers a period of relative economic stability and growth (2003-2006), while the latter part (2007-2009) covers the 2007-2008 credit crunch, the 2008 global financial markets crash and the subsequent economic recession. For robustness, we also test the role of ambiguity in systemic banking performance over the longer period 1999-2015 after extracting EUUP-based ambiguity information from S&P500 index (SPX) returns data.

We rely on the CU and α-MEP specifications in our ambiguity elicitation because of the probabilistic and lottery-like features of financial options instruments (i.e., asymmetric payoffs and bets on volatility), and the sophisticated nature of options investors. We find that ambiguity from banking equity option prices has a significant positive effect on systemic banks' downside risk, as well as credit and market risks. Ambiguity among put option holders has a positive effect on systemic banking risk. For call option traders, higher ambiguity is associated with higher banking risk. In sum, ambiguity from systemic banks' options prices exacerbates the levels of risk and instability present in the banking system, especially in times of heightened uncertainty. This holds after controlling for important option-based and market determinants of banking risk, such as liquidity, size, fat tail risk, implied volatility, and volatility of volatility. Our results are robust to different option-moneyness levels, alternative ambiguity measures (including EUUP-based ones from IYF and SPX), and under various data/model specifications (i.e., using daily or monthly price and volatility data). They also hold using panel regressions that relate ambiguity to "too-big-to-fail" bank-specific risk (after controlling for standard characteristics). We further show that the elicited ambiguity information (*AMB*) from option prices and IYF data is significantly negatively associated with important aspects of real economic activity, including capacity utilization (production), total non-farm payrolls (net hiring) and overall economic output (proxied by the CFNAI). This finding concurs with recent evidence by Berger et al. (2017) and Jin et al. (2019) on the effects of economic policy uncertainty on liquidity creation and earnings management. We provide an ambiguity-based behavioral explanation to the uncertainty-performance linkage. An alternative and related explanation to this association is the potential role played by disagreement (sentiment risk) in exacerbating systemic risk (see e.g, Basak, 2000; Yan, 2008; Baker et al., 2016).[1] Recent research indicates that differences of opinion and disagreement affect asset prices, default propensities and liquidity, and also explain a number of international finance anomalies (Osambela, 2015; Dumas et al., 2017).

We contribute to the literature in two ways. First, we establish a linkage between option investors' (subjective) behavior in the marketplace and U.S. systemic banks performance. Specifically, we provide evidence of ambiguity in financial market transactions involving the twelve too-big-to-fail banks and show how option holders' ambiguity behavior exacerbates the amount of risk present in the financial system. Second, we confirm the adverse effect of uncertainty on economic activity by documenting how ambiguity from systemic banks' equity options brings losses to the real economy. Our study is the first to empirically link investor behavior and ambiguity to systemic banks' risk in a natural market setting. It also indirectly relates to extant business and management research on the relationship between ambiguity and firm or industry performance (e.g., Mosakowski, 1997; King and Zeithaml, 2001; Petkova et al., 2014; Friberg and Seiler, 2017).

The remainder of the paper is organized as follows. Section 2 presents our theory and hypotheses, and describes the behavioral frameworks we use to elicit ambiguity from systemic banks' option prices (and IYF as well as SPX intraday returns). Section 3 covers our data and empirical methods. Section 4 discusses findings and resulting implications. Section 5 concludes.

2. Theory and Hypotheses

Over the years, Knight (1921), Keynes (1921), and many others (Allais, 1953; Ellsberg, 1961; March, 1978; Quiggin, 1982) have recognized that while risk is characterized by events with measurable probability outcomes, under uncertain conditions such probabilities may not be fully knowable and decision-makers are more doubtful or ambiguous about the accuracy of their probability estimates. Such behavior results in subjective discounting, non-additive probability weighting and subjective valuation when choices are made under uncertainty (Hogarth and Kunreuther, 1989; Samuelson, 2008). We interpret ambiguity in this paper as investors' propensity to deviate from

[1] While the focus of this research is on the role of ambiguity in systemic banking performance, further analysis (using monthly multivariate/orthogonalized regressions) indicates that both ambiguity and sentiment increase systemic banking risk suggesting potential interactions between the two concepts (especially under α-MEP where pessimism and optimism information overlaps with disagreement). The sentiment indicator used in this analysis is a composite score of several disagreement and sentiment proxies including: Investor Sentiment Index Aligned (AISI, Huang et al., 2014), Consumer Confidence Index (CCI), Investors Intelligence Bearish Index (IBEAR, Fisher and Statman, 2000), Investor Sentiment Index (ISI, Baker and Wurgler, 2006), and the University of Michigan Consumer Sentiment Index (UMCSI).

Bayesian valuation because of a lack of complete information regarding the future realizations of market returns/volatility and investors' inability to rule out the number of distributions associated with their valuation heuristics and estimates (see the related Brownian motions in Eqs. (A3-A4) in Appendix A). This interpretation is closely related to that - from applied psychology - of Mosakowski (1997) and Einhorn and Hogarth (1985), and is also comparable to the lack of information clarity definition by Friberg and Seiler (2017). The aforementioned deviations affect the probabilities (i.e., probabilistic ambiguity) and investor uncertainty preferences (i.e., aversion or seeking). We, thus, build on notions of non-additive probabilities and decision weights (e.g., Hogarth and Einhorn, 1990; Abdellaoui et al., 2005; Chateauneuf et al., 2007; Abdellaoui et al., 2011) to elicit ambiguity information from financial derivatives transactions. Under CU (α-MEP), ambiguity aversion (pessimism) can be viewed as investors' tendency to overweight events with bad outcomes (relative to objective probabilities) when faced with uncertainty, while ambiguity-seeking (optimism) is proxied by investors' propensity to overweight good, but less probable, outcomes displaying gambling or uncertainty-loving comportment (see Schmeidler, 1989; Ghirardato et al., 2004; Chateauneuf et al., 2007). The EUUP-based ambiguity information by Brenner and Izhakian (2018), examined herein for robustness, captures the degree of probabilistic ambiguity in the marketplace but not necessarily the direction of ambiguity. The latter is reflected in our α-MEP ambiguity indicators (e.g., ambiguity pessimism) and is also partly proxied by our CU-based ambiguity measures.

2.1. Ambiguity frameworks

Different from Leiblein et al. (2017) who use signaling theory to account for subjective biases in Black-Scholes-Merton (BSM) valuation, we model ambiguity based on the Choquet utility (CU): a rank-dependent specification nested within cumulative prospect theory (see Schmeidler, 1989; Dow and Werlang, 1992; Hey et al., 2010; Driouchi et al., 2018), and also using a framework related to CU: multiple priors MEP (in particular α-MEP) which has been examined more broadly in finance and portfolio selection research (see e.g., Uppal and Wang, 2003; Maenhout, 2004). The α-MEP ambiguity specification goes beyond the assumption of extreme pessimism or complete aversion to uncertainty of the standard MEP in that, through the use of decision weights, it accommodates both optimistic and pessimistic appraisals. Overall, we relax the assumption of uncertainty-neutrality (i.e., which consists of assigning equal weights to positive and negative prospects) characterizing the standard BSM framework by explicitly incorporating ambiguity in the stochastic process driving stock and option prices, thus allowing the possibility of multiple distributions for valuation (see Appendix A contrasting ambiguity-free A1 versus ambiguity-contaminated

A3 (CU) and A4 (MEP)). In these broader settings, option investors' expectations of future underlying stock prices depend on their degree of ambiguity and the implicit decision weights assigned to positive vs. negative realizations. As such, exercise probabilities are adjusted upward or downward (i.e., in a non-additive probabilistic sense: see Appendix B) subject to ambiguity (Einhorn and Hogarth, 1986; Hogarth and Kunreuther, 1989). Option investors/traders are, consequently, more prone to biases and errors in valuation, trading execution and decision-making because of such adjustments.

2.1.1. Choquet ambiguity

Extending the Black-Scholes (1973) fundamental valuation equation (e.g., see also Boyarchenko and Levendorskii, 2007; Driouchi et al., 2018) to the case of Choquet ambiguity based on Eq. (A3), we obtain the following specification for ambiguity-adjusted option price *O* with underlying asset *S*:

$$\frac{\partial O}{\partial t} + S^2 \frac{1}{2}\frac{\partial^2 O}{\partial S^2}(s\sigma)^2 + \left(r' - \delta'\right)\frac{\partial O}{\partial S}S - r'O = 0 \tag{1}$$

where:

$$r' = r + m\frac{[r - (\mu + m\sigma)]}{s^2\sigma} \text{ and } \delta' = \delta - \frac{(m + s^2\sigma - s\sigma)[(\mu + m\sigma) - r]}{s^2\sigma}$$

with:

$$m = 2c - 1 \text{ and } s = \sqrt{4c(1-c)}$$

Ambiguity score and capacity variable c captures investors' ambiguity, with $0 < c < 0.5$ interpreted in the CU literature as ambiguity aversion, pessimism (negative m) and under- (over-) weighting of good (bad) outcome probabilities, $0.5 < c < 1$ implying ambiguity-seeking, optimism (positive m) and over- (under-) weighting of good (bad) outcome probabilities (see Chateauneuf et al., 2001; Kast and Lapied, 2010; Agliardi, 2017), and equal weight $c = 0.5$ (similar weighting) corresponding to the traditional ambiguity-neutral and Bayesian framework (see e.g., Kast and Lapied, 2010; Abdellaoui et al., 2011; Agliardi et al., 2016; and Driouchi et al., 2018). Score c affects the discount rate, dividend yield and volatility used in the behavioral valuation. Under MEP, ambiguity affects the discount rate and dividend yield only. Reflecting investors' degree of ambiguity perceptions over time, ambiguity proxy c does not fully delineate ambiguity attitudes from the overall degree of probabilistic ambiguity (Baillon et al. 2017; Baillon and L'Haridon, 2016). It is indicative of direction but also contains confounding information about ambiguity perceptions. This is due to the use of one score, rather than two, to describe the ambiguity behavior characterizing

Eq. (A3). An interesting extension could consist of separating our c indicator into an uncertainty score of likelihood insensitivity and a pure index of ambiguity aversion or pessimism (e.g., see Abdellaoui et al., 2011; Baillon et al., 2017), and study the economic implications of each component using source functions. For further validation of our findings (and to remedy the above CU limitation),[2] we use the α-MEP specification which captures both pessimism and optimism under ambiguity, and the EUUP-based probabilistic ambiguity proxy by Brenner and Izhakian (2018).

Our CU specification is in accord with the descriptive model of Einhorn and Hogarth (1985) and Hogarth and Einhorn (1990) on judgment under ambiguity with behavioral adjustments and non-additive probabilities. In such a setting m and s are subjective adjustments factors, caused by ambiguity score c, affecting the valuation process and its inputs and inducing potential biases in option exercise, termination and trading execution. m captures investors' pessimism ($m < 0$ and $c < 0.5$) or optimism ($m > 0$ and $c > 0.5$) about expected growth rates (returns) while s is a subjective volatility scaling factor. These two input variables can take a number of functional forms, with the special ambiguity-neutral case satisfying $m = 0$ and $s = 1$ (i.e., more accurate or normative case $c = 0.5$, see e.g., Kuhnen and Melzer, 2018). In the MEP setting, ambiguity affects only the drift of the Brownian motion and not the diffusion component (see Eq. (A4)). r, μ, σ and δ stand for the risk-free interest rate, rate of return on S, stock volatility and the objective dividend yield, respectively. Each of these four factors is adjusted to account for ambiguity, through m and s under CU (and m only in the MEP specification with objective volatility), as shown in Eqs. (1-3). Via their second components, r' and δ' proxy for investors' tendency to deviate from risk-neutrality under uncertainty. r' is analogous to a subjective discount rate (e.g., for cases where $r > \mu + m\sigma$, $r' < r$ when $c < 0.5$ and $r' > r$ when $c > 0.5$) whereas δ' is an ambiguity multiplier or subjective dividend yield. In the absence of ambiguity ($m = 0$ and $s = 1$), the above reduces to the ambiguity-neutral and canonical BSM case (where $r' = r$ and $\delta' = \delta$) resulting in Eqs. (A2) and (A2.1). The MEP ambiguity specification can be viewed as a special case of CU under a number of conditions.

Analogous to Merton (1973), but explicitly accounting for Choquet ambiguity, solutions to Eq. (1) for a European call option O_{call} with exercise price X and maturity T are:

$$O_{call}^{CU} = S_0 e^{-\delta' T} N(d'_1) - X e^{-r' T} N(d'_2) \quad (\forall\ c\ \in]0,1[) \tag{2}$$

where:

[2] In additional analysis that consists of regressing our CU-based measures of ambiguity on α-MEP counterparts and using the residual-based ambiguity proxy as an indirect way to disentangle probabilistic ambiguity from ambiguity attitudes in Eq. (19), we find that most of our results on the positive effect of ambiguity on systemic banking risk hold.

$$d'_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r' - \delta' + \frac{1}{2}(s\sigma)^2\right)T}{s\sigma\sqrt{T}} \text{ and } d'_2 = d'_1 - s\sigma\sqrt{T}$$

The above differs from the ambiguity-free BSM Eq. (A2.1), in that we use ambiguity-adjusted factors δ' and r' (instead of r and δ) and subjective probabilities $N(d')$ in the valuation (see Eqs. (1-3)).[3] Option exercise probabilities here are directly affected by Choquet ambiguity through r', δ', m and s, due to ambiguity score c, causing behavioral deviations from Bayesian appraisal and resulting in over-execution (type 1 errors: exercise of out-of-the money (OTM) options) and under-execution (type 2 errors: early or suboptimal exercise/termination of in-the-money (ITM) options)) problems (see e.g., Coff and Laverty, 2007; Leiblein et al., 2017).[4]

Similarly, solutions to Eq. (1) under Choquet ambiguity for a European put option O_{put} (i.e., giving the set of possible put prices under ambiguity) with exercise price X and maturity T are:

$$O_{put}^{CU} = Xe^{-r'T}N(-d'_2) - S_0 e^{-\delta' T}N(-d'_1) \quad (\forall\, c \in]0,1[) \tag{3}$$

r' and δ' are as defined above. $N(.)$ is the standard cumulative normal distribution function. $N(-d'_1)$ and $N(-d'_2)$ are once again *ambiguity-based* option exercise probabilities indicative of uncertainty in valuation and trading behavior. Contrary to the standard BSM framework where indifference towards uncertainty is assumed (due to hedgeability), put-call parity should not be expected to hold in this setting as call and put holders are unlikely to share similar ambiguity characteristics. This is further explained by investors' differential predispositions towards potential gains and losses arising from trading calls vs. puts and the subjective nature of the $N(d')$ functions (unequal decision weights and adjustments to the probabilities). The above once again reduces to single discounting and "objective" valuation when c = 0.5 (equal decision weights and special case A2.1).

Eqs. (2-3) are, thus, natural extensions of the Black-Scholes call and put option formulae to the more general case of Choquet ambiguity with m and s adjustments. This also holds for MEP ($m \neq 0$ and $s = 1$ in Eqs. (2-3)). By

[3] Involving non-additive probabilities under ambiguity, Eq. (2) can be rewritten as (see A2.1 for d_1 and d_2):

$$O_{Call}^{CU} = S_0 e^{(-\delta T)}N(d_1)\cdot w'_1 - Xe^{-rT}N(d_2)\cdot w'_2$$

with decision weights w'_1 and w'_2 defined as (note $w' = 1$ reduces the above to the BSM benchmark in A2.1):

$$w'_1 = \frac{N\left(\frac{1}{s}d_1 + \varphi_1\right)}{N(d_1)} \cdot e^{\left(\frac{(m+s^2\sigma - s\sigma)[(\mu+m\sigma)-r]}{s^2\sigma}T\right)} \text{ and } w'_2 = \frac{N\left(\frac{1}{s}d_2 + \varphi_2\right)}{N(d_2)} \cdot \frac{1}{e^{\left(m\frac{[r-(\mu+m\sigma)]}{s^2\sigma}T\right)}}$$

where:

$$\varphi_1 = \frac{T\{m[r-(\mu+m\sigma)] + (m+s^2\sigma - s\sigma)[(\mu+m\sigma)-r]\}}{s^3\sigma^2\sqrt{T}} + \frac{0.5\sigma^2 T(s-1)}{s\sigma\sqrt{T}};\ \varphi_2 = \frac{T\{m[r-(\mu+m\sigma)] + (m+s^2\sigma - s\sigma)[(\mu+m\sigma)-r]\}}{s^3\sigma^2\sqrt{T}} - \frac{0.5\sigma^2 T(s-1)}{s\sigma\sqrt{T}}$$

[4] For instance under CU, $r' < r$ ($r' > r$) can lead to option overvaluation (undervaluation) when $c < .5$ ($c > .5$) if $r > \mu + m\sigma$. As another illustration of bias, if for example $c = .25$ ($c = .75$), $\sigma = .45$ and $r = \mu = .05$, the probability to exercise a put option with underlying price $S_0 = 100$, strike price $X = 100$ and maturity $T = 2$ becomes .49 (.59) compared to risk-neutral probability .56.

back-solving Eqs. (2-3) for ambiguity parameter c, given market-observed option prices, one can infer the level of ambiguity implied by traded options prices under CU. We name this c variable ambiguity score AMB^{CU} throughout the rest of the paper. The elicitation is achieved by a simple minimization of the distances between the observed option market prices and above models' intrinsic values, effectively inverting Eqs. (2-3) as follows (see also Abdellaoui et al., 2011 and their experiment-based elicitation):

$$AMB^{CU} = O^{-1}_{call/put}(X, S, T, r, \delta, \mu, \sigma) \tag{4}$$

2.1.2. Alpha-MaxMin multiple priors ambiguity (alpha-MEP)

In addition to the above, we model ambiguity using the α-MEP specification (a variant of the standard MEP framework) focusing on uncertainty in drift only. The intuition behind this specification is that investors consider something akin to a weighted average between their pessimistic (worst/minimum) and optimistic (best/maximum) assessments when cognitively appraising option opportunities under ambiguity. Related to CU, the fundamental valuation equation under MEP is subsumed by Eq. (1) (special case s =1). As such, the α-MEP-based option price can be expressed as follows:

$$O^{alpha-MEP} = \alpha \cdot \arg\max_c O^{MEP}(X, S, T, r, \delta, \mu, \sigma, c) + (1-\alpha) \cdot \arg\min_c O^{MEP}(X, S, T, r, \delta, \mu, \sigma, c) \tag{5}$$

Nested in Eqs. (2-3), O^{MEP} is the value of the option under the multiple priors ambiguity specification where $0 < c < 1$ (and $m \neq 0$ and s = 1). $O^{alpha\text{-}MEP}$ is the weighted average of the maximum and minimum O^{MEP} values under c. Ambiguity attitude or weighting variable α reflects the trade-off between the best and worst option valuation cases (with $0 \leq \alpha \leq 1$). As mentioned, ambiguity does not affect the diffusion component of the Brownian motion (see Eq. (A4)) herein. By back-solving Eq. (5) for parameter α, one can infer investor ambiguity from traded options prices under α-MEP. We name this α variable ambiguity score $AMB^{alpha\text{-}MEP}$ throughout the rest of the paper. For ease of interpretation, $AMB^{alpha\text{-}MEP}$ will reflect the weight assigned to pessimistic outcomes.

2.1.3. Alternative ambiguity specification

Expected utility with uncertain probabilities (EUUP)

For robustness, we also model ambiguity using the EUUP framework of Brenner and Izhakian (2018) and Izhakian and Yermack (2017). EUUP-based ambiguity is defined as follows:

$$AMB^{BI} = \frac{1}{w(1-w)} \cdot \begin{pmatrix} E[\Phi(r_0;\mu,\sigma)]Var[\Phi(r_0;\mu,\sigma)] \\ +\sum_{i=1}^{k} \begin{matrix} E[\Phi(r_i;\mu,\sigma) - \Phi(r_{i-1};\mu,\sigma)] \\ \times Var[\Phi(r_i;\mu,\sigma) - \Phi(r_{i-1};\mu,\sigma)] \end{matrix} \\ +E[1-\Phi(r_k;\mu,\sigma)]Var[\Phi(r_k;\mu,\sigma)] \end{pmatrix} \quad (6)$$

where $\frac{1}{w(1-w)}$ is a scaling factor, Φ denotes the cumulative distribution function of the standard normal distribution and $P(r \geq r_f) = 1 - \Phi(r_f;\mu,\sigma)$, k is the number of intervals in pooling returns, with a total number of bins of k+2, μ is the daily mean of intra-day five-minute returns, and σ is the realized variance of intra-day five-minute returns. Following Brenner and Izhakian (2018), we use a value of -6% for r_0 and k = 60. In our research, we elicit AMB^{BI} scores from IYF (and SPX) using intraday data.

Since derivatives markets are known to lead primary asset markets in terms of information discovery (lead-lag association) and, potentially, risk contagion (Poon and Granger, 2003; Kelly et al., 2016), we examine the extent to which banking investors' ambiguity in the option market is associated with the subsequent degree of risk characterizing the twelve major systemic banks in the equity and credit markets. For robustness, we also study the role of ambiguity from IYF in banking performance. We focus on financial institutions because of the high uncertainty surrounding the banking sector over the past decade (Boyarchenko 2012; Kelly et al., 2016; Vallascas et al., 2017). Our aim is to examine from a behavioral theory perspective whether, and the extent to which, ambiguity variables *AMB* contribute to systemic banks' risk and decrease real economic activity. We are concerned with downside, systematic (market) and credit risks as key indicators of systemic banks' performance.

2.2. Hypotheses

As subjective behavior tends to limit investors' ability to effectively hedge their trading positions and results in more errors and losses in options trading (over- and under-execution) (Poteshman, 2001; Poteshman and Serbin, 2003), ambiguity elicited from option prices should be positively associated with downside risk. Due to disagreement, suboptimal investment allocation and speculative trades under uncertainty (see e.g., Bargeron et al., 2014; Baker et al., 2016; Dicks and Fulghieri, 2019), ambiguity reflected in banks' equity options should also be positively associated with systematic risk. Further, because of induced put-call parity violations (Cremers and Weinbaum, 2010; Chen et al., 2019), the inability to fully hedge such violations and the leveraged nature of options (see Borochin and Yang, 2017), ambiguity should be positively associated with credit risk. Differences in moneyness expectations and misspecification around exercise probabilities should also result in more leveraged and riskier option positions, and thus higher systemic risk. This holds for both put and call options instruments. Call and put option-elicited ambiguity should then also explain positive changes in systemic banks' risk. The above leads to the following hypothesis for our 2003-2009 too-big-to-fail banking context:

Hypothesis 1. *Ambiguity in the call and put options markets is positively associated with systemic banks' risk.*

Additionally in times of crisis-induced turbulence, ambiguity behavior should be more prevalent in the economic environment and financial markets. In such conditions, economic agents, investors/traders and other decision-makers are more prone to errors and biases due to Knightian uncertainty, increasing disagreement, lower sophistication and highly incomplete information (see Easley and O'Hara, 2010; Leiblein et al., 2017). Ambiguity averse investors can be more averse because of limited market participation, higher demand for self-insurance and flight-to-quality behavior (Alary et al., 2013; Dicks and Fulghieri, 2019). Ambiguity-seeking investors might be more erratic, aggressive and miscalibrated as a result of growing speculation and uncertainty-loving behavior (e.g., shorting calls) in the marketplace (see e.g., Cao et al., 2005; Tarashev, 2007). This implies that higher ambiguity should further increase risk in the financial system and financial market instability. This leads to the following hypothesis:

Hypothesis 2. *The positive relationship between ambiguity and systemic banks' risk is more prevalent during times of high economic uncertainty and crisis-induced turbulence.*

3. Data, variables and methods

3.1. Data

We study the ambiguity behavior of call and put option investors in major U.S. banks during 2003-2010. Options data (dividend-adjusted) on the twelve systemic or too-big-to-fail financial institutions (tickers C, GS, JPM, MS, USB, WFC, BS, LEH, BAC, MER, WM, WB)[5] are obtained from OptionMetrics over a period of 1700 days. The data includes daily settlement prices for the call and put options ($O_{call/put}$), their maturity dates (T), exercise prices (X) and open-interest (OI) information. Settlement prices for the underlying bank equities and market capitalization data are used to estimate downside risk (DR, downside realized volatility), option-elicited ambiguity indicators (AMB^{CU} and $AMB^{alpha\text{-}MEP}$), and option implied volatility (IV). For AMB^{BI}, we follow the approach by Brenner and Izhakian (2018) and infer ambiguity information primarily from the iShares Dow Jones US financial sector ETF (IYF). We

[5] Namely: Citigroup, Goldman Sachs, JP Morgan, Morgan Stanley, US Bancorp, Wells Fargo, Bear Stearns, Lehman Bros, Bank of America, Merrill Lynch, Washington Mutual, and Wachovia. These twelve systemic banks were at the center of the 2007-2009 credit crisis and were viewed as the largest security firms and commercial banks in the U.S. (see also Eichler et al., 2011; Gande and Kalpathy, 2017).

also estimate and use systematic risk (*EBETA*, historical CAPM-beta) and credit risk (*CR*, realized volatility of the 3-month ICE LIBOR rate) as alternative dependent variables in our systemic banking risk analysis.[6] Our dependent variables (*DR*, *EBETA* and *CR*) are important indicators of overall banking performance from a market standpoint. Skewness (*SKEW*) or tail risk, and volatility of volatility (*SDVIX*, standard deviation of VIX) are obtained from the CBOE through its SKEW and VIX indices. *IV*, *OI*, *SKEW* and *SDVIX* serve as (daily and monthly) control variables from the options market and are established determinants of market risk. In our additional results using panel regressions, we also control for bank size.

We follow standard procedure for option contract selection in terms of maturity matching and data specifications (see e.g., Swidler and Wilcox, 2002; Friesen et al. 2012; Bargeron et al., 2014). Spanning the recent great recession (2007-2009) and the preceding more stable period (2003-2006), our sample allows comparing and contrasting banking investor ambiguity across different uncertainty regimes (higher vs. lower). IVs and AMBs are computed, using both daily and monthly data, from settlement prices of the selected option contracts, inferred from our ambiguity-based Eqs. (2, 3 and 5). Following Brenner and Izhakian (2018) and their elicitation approach, we compute our AMB^{BI} score using the intra-day returns of IYF and SPX for additional robustness. Yields on U.S. T-bills and T-bonds over the maturity of each contract are used as risk-free rates (r) in computing IVs and AMBs per bank, and aggregate indicators of ambiguity ($AMB^{banking}$) for the overall sample (see the Explanatory variables sub-section for our $AMB^{banking}$ specifications). The annualized average daily returns per bank over the previous year are employed to estimate its expected return (μ).[7] For the real economy implications covered in Section 4.3, monthly economic activity data are obtained from the Board of Governors of the Federal Reserve System (on capacity utilization), the Bureau of Labor Statistics (non-farm payrolls) and the Chicago Fed website (CFNAI).

3.2. Variables

3.2.1. Dependent variables

Downside Risk (*DR*). DR is estimated as the annualized ex-post sample standard deviation of negative daily returns, equivalent to semi-variance, for each banking stock (see Low, 2004):

[6] We also use conditional VaR (CVaR) and Merton distance-to-default (DD) as alternative indicators of banking risk for further validation and robustness.

[7] We also collect data for realized skewness and kurtosis as additional controls in the regressions; our findings are robust to the inclusion of these variables. The effect of $AMB^{banking}$ on systemic banking risk is also generally maintained when separately controlling for price-to-book ratio and lagged VaR dynamics in a set of bivariate regressions.

$$DR_{t,T}^{B} = \sqrt{\sum_{i=t}^{T} \frac{\left(r_i^{B,d}\right)^2}{N-1} \times 252} \tag{7}$$

where $DR_{t,T}^{B}$ is the downside volatility of bank *B* calculated using returns from time *t* to option maturity *T*, $r_i^{B,d}$ is the downside logarithmic return of bank *B* on day *i*, and N is the number of observations. From this, the weighted average downside volatility for the sample of banks examined is obtained as follows (w_i is based on market capitalization):

$$DR_{t,T}^{banking} = \sum_i w_i \ DR_{t,T}^{B} \tag{8}$$

Systematic Risk (EBETA). EBETA for each bank is computed as (see Alexander, 2001):

$$\hat{\beta}_t^{\lambda,B} = \frac{Cov_\lambda(r_t^B, r_t^M)}{var_\lambda(r_t^M)} \tag{9}$$

where:

$$Cov_\lambda(r_t^B, r_t^M) = \lambda\left(Cov_\lambda(r_{t-1}^B, r_{t-1}^M)\right) + (1-\lambda)(r_t^B r_t^M)$$

$$var_\lambda(r_t^M) = \lambda\left(var_\lambda(r_{t-1}^M)\right) + (1-\lambda)(r_t^M)^2$$

r_t^B is the return of bank *B* on day *t*, r_t^M is the return on the market index (S&P 500), λ is a persistence parameter of the historical covariance between bank *B* returns and index returns, and $\hat{\beta}_t^{\lambda,B}$ is bank *B*'s systematic risk. The weighted average *EBETA* for the set of major banks examined is then obtained as follows:

$$\hat{\beta}_t^{\lambda,Banking} = \sum_i w_i \hat{\beta}_t^{\lambda,B} \tag{10}$$

Credit Risk (CR). CR is computed by taking the annualized ex-post sample standard deviation of daily changes of the 3-month ICE LIBOR rate (see Alessandri and Nelson, 2015):

$$CR_{t,T} = \sqrt{\sum_{i=t}^{T} \frac{\left(r_i^L - \overline{r_{t,T}^L}\right)^2}{N-1} \times 252} \tag{11}$$

where $CR_{t,T}$ is the volatility of the 3-month LIBOR rate changes from time *t* to *T*, r_i^L is the logarithmic change of the 3-month LIBOR rate, $\overline{r_{t,T}^L}$ is the average logarithmic change from time *t* to *T*, and N is the number of observations. For robustness, we also use Merton's distance-to-default measure as an alternative *CR* proxy.

3.2.2. Explanatory variables

Ambiguity (AMB). Based on Eqs. (2-5) and market capitalization weighting, we use systemic banking indicators that capture option investors' ambiguity about the banking sector's prospects (represented by the twelve major or too-big-to-fail U.S. banks). We rely on the market capitalization of each bank to reflect its weight and size in the sector.

Our aggregate CU-based indicators of ambiguity ($AMB^{CU,banking}$) elicited from calls and puts for too-big-to-fail institutions are, respectively, as follows:

$$AMB_{calls}^{CU,banking} = \sum_i w_i AMB_{calls}^{CU,B} \ , \ 0 < AMB_{calls}^{CU,B} < 1 \tag{12}$$

$$AMB_{puts}^{CU,banking} = \sum_i w_i AMB_{puts}^{CU,B} \ , \ 0 < AMB_{puts}^{CU,B} < 1 \tag{13}$$

$$AMB_{SUMDEV}^{CU,banking} = \left(\left| AMB_{calls}^{CU,banking} - 0.5 \right| + \left| AMB_{puts}^{CU,banking} - 0.5 \right| \right)/2 \tag{14}$$

where w_i is the weight per major bank B in the sample, and $AMB^{CU,B}$ from Eq. (4) is the degree of ambiguity elicited from call and put options written on B's stock under CU. $AMB^{CU,B}$ for bank B is backed-out by dynamically minimizing the distance between observed options prices and model intrinsic values such that (and in line with Eq. (4)):

$$AMB_{t,T}^{CU,B} = O^{-1}(X, S_t^B, T, r_t, \delta_t^B, \mu_t^B, \sigma_t^B)_{0<c<1} \tag{15}$$

where O^{-1} stands for the inverse of the Choquet-based option pricing functions (Eqs. (2-3)) given in Section 2.1. Composite score $AMB^{CU}{}_{SUMDEV}$ is the sum of deviations from the unambiguous benchmark score of 0.5 and reflects the overall level of Choquet ambiguity characterizing systemic banks in the options market.

Similarly, under the α-MEP specification:

$$AMB_{calls}^{alpha,banking} = \sum_i w_i AMB_{calls}^{alpha,B} \ , \ 0 < AMB_{calls}^{alpha,B} < 1 \tag{16}$$

$$AMB_{puts}^{alpha,banking} = \sum_i w_i AMB_{puts}^{alpha,B} \ , \ 0 < AMB_{puts}^{alpha,B} < 1 \tag{17}$$

$$AMB_{SUM}^{alpha,banking} = \left(AMB_{calls}^{alpha,banking} + AMB_{puts}^{alpha,banking} \right)/2 \tag{18}$$

where w_i is as defined before, and $AMB^{alpha,B}$ is the ambiguity attitude (i.e., pessimism) elicited from call and put options written on B's stock. $AMB^{alpha,B}$ for bank B is backed-out by inverting Eq. (5). Composite score $AMB^{alpha}{}_{SUM}$ captures the overall degree of ambiguity pessimism in the (systemic) banking options market.

Applicable to both call and put options transactions, the $AMB^{banking}$ indicators reflect investors' ambiguity concerning the prospects of the U.S. banking sector and particularly its twelve systemic or too-big-to-fail institutions.

Accounting for option moneyness considerations (OTM and ITM), both sets of indicators consider when $S > X$ (or $X < S$) depending on whether we are dealing with call or put options (i.e., upside vs. downside) prospects. Our panel regressions analysis and associated supplementary results examine the effect of ambiguity AMB^{B} per bank on systemic risk. This is achieved for further validation and to provide additional insights into the ambiguity-bank performance linkage. As discussed above, EUUP-based AMB^{BI} from Eq. (6) is used for robustness and is elicited from IYF (SPX) data when compared against AMB^{CU} and AMB^{alpha} ($AMB^{CU}{}_{SUMDEV}$ and $AMB^{alpha}{}_{SUM}$) dynamics.

3.2.3. Control variables

In order to isolate the effect of ambiguity on systemic banks' risks, we control for standard banking performance determinants from the financial options markets literature (Swidler and Wilcox, 2002; Friesen et al., 2012), such as implied volatility, skewness, volatility of volatility, and option market liquidity and size. We use standard implied volatility (*IV*) as a banking risk determinant and employ option-based control variables for liquidity, fat tail risk, and volatility of volatility through open-interest (*OI*) data, the CBOE SKEW index (*SKEW*) and the standard deviation of VIX (*SDVIX*) respectively (see Appendix C for variables specification). Capturing investors' forward-looking risk expectations (Poon and Granger, 2003) and helping to distinguish risk-related perceptions from ambiguity behavior, *IV* is computed as the weighted average option implied volatility for the set of banks examined. Proxying for size and liquidity effects, *OI* is calculated as the aggregated open-interest (calls and puts) for the twelve banks studied. Accounting for so-called unk-unks, or volatility of volatility effects, *SDVIX* is computed as the annualized standard deviation of daily changes in VIX (commonly known as the 'fear gauge') based on a 22-day moving estimation window. Reflecting tail risk and containing potential risk aversion information not captured by VIX, *SKEW* is obtained from the CBOE SKEW index. For further robustness, we also verify if our conclusions hold over longer time periods and after controlling for NBER recessions.

As aggregate measures of investors' tendency to deviate from Bayesian valuation, our $AMB^{banking}$ scores should help explain fluctuations in banking risk beyond those captured by the above (daily and monthly) measures and controls. We use multivariate regression analysis in our empirical tests concerning Hypothesis 1 (H1), and also employ variance decomposition to verify whether ambiguity effects are more pronounced in more uncertain times and analyze how its effects on banking risk vary across uncertainty regimes (Hypothesis 2: H2). The effect of ambiguity per bank, proxied by AMB^{B}, on systemic risk is examined using panel regressions.

3.3. Methods

3.3.1. Multivariate regression specification

To examine the effect of ambiguity on systemic banking risk, we test the following (daily and monthly) lead-lag time-series option-based regression models:

$$Risk_{t+1,T}^{banking} = \beta_0 + \beta_1 AMB_{t,T}^{banking} + \beta_2 IV_{t,T}^{banking} + \beta_3 SKEW_t + \beta_4 OI_t^{banking} + \beta_5 SDVIX_t + \varepsilon_{t+1} \qquad (19)$$

where $Risk_{t+1,T}^{banking}$ is the risk of the twelve systemic banks examined, $AMB_{t,T}^{banking}$ is our systemic banking indicator of ambiguity (i.e., from Eqs. (12-14) under CU and Eqs. (16-18) under α-MEP) elicited from observed call and put option prices written on these banks' stocks (based on AMBs from Eqs. (4) and (5)) and using AMB^{BI} from the IYF ETF (i.e., Eq. (6)), and $IV_{t,T}^{banking}$ stands for the option implied volatility of these banks. $SKEW_t$, $OI_t^{banking}$ and $SDVIX_t$ are controls for other option-related information (fat tail, size and liquidity, and volatility of volatility effects, respectively). Eq. (19) tests the effect of ambiguity on systemic bank risk after controlling for option-based risk, tail risk, liquidity risk and size, and volatility of volatility dynamics in the regressions.[8] Eq. (19) is compared to the risk-based multivariate regression specification, without the *AMB* terms, for hypothesis validation. Newey and West (1987) (NW) adjusted standard errors are used to correct for potential autocorrelation issues in the daily data.[9] Our analysis is applied on daily data (2003-2006 vs. 2007-2009) and then repeated on monthly data (2003-2009) for robustness. Panel regression analysis (based on Eq. (19) but controlling for fixed effects and bank-specific information) is also implemented for additional validation. To mitigate cross-section dependence concerns associated with panel data (see Pesaran, 2004), we employ and report cross-sectional dependence robust standard errors based on Driscoll and Kraay (1998) in our bank-specific panel regressions.

3.3.2. Variance decomposition

We use variance decomposition to examine the relative influence of ambiguity ($AMB^{banking}$), compared with other explanatory variables, on U.S. systemic banking risk across two different uncertainty regimes, namely 2003-2006 vs.

[8] Adding these control variables in the regressions should help reduce potential confounding effects from alternative economic explanations (e.g., skewness, liquidity, unk-unk and risk aversion).

[9] Following Christensen and Prabhala (1998), heteroskedasticity and autocorrelation consistent (HAC) standard errors are employed based on Newey and West (1987) to account for autocorrelation issues in the daily data. Serial correlations in regression residuals were detected and confirmed by the Breusch–Godfrey LM tests. Lag selections are based on Andrews (1991). In line with Sun et al. (2008) and Bekaert and Hoerova (2014), our results are also robust to standard error adjustments using longer lag lengths of 60 (2*overlapped period) based on the extent of overlapping in the construction of our systemic measures (see Christensen and Prabhala, 1998).

2007-2009. We employ the forecast error variance decomposition (FEVD) approach, due to co-integration, to measure the proportion of subsequent variable variance due to own shocks (i.e., *DR*, *EBETA*, *CR*) vs. shocks from other variables (i.e., *AMB, IV, SKEW, OI, SDVIX*). Underlying the FEVD is a standard vector error correction model (VEC) of the form:

$$\Delta Y_{k,t} = \alpha_{k,0} + \sum_{j=1}^{k-1}\sum_{i=1}^{n} \alpha_{j,i}\Delta X_{j,t-i} + \sum_{i=1}^{n} \alpha_{k,i}\Delta Y_{k,t-i} + \varepsilon_{k,t} \tag{20}$$

where $\Delta Y_{k,t}$ is the first difference of the dependent variable at time t, $\Delta X_{j,t-i}$ is the i-step lagged first difference of independent variable j, k is the total number of variables in the VEC system, and n is the total number of lags. The portion of variance $var\left(\Delta Y_{k,t+n} - \Delta Y_{k,t+n|t}\right)$ due to shocks from ε_k is:

$$FEVD_{k,j,n} = \frac{\sigma_{\varepsilon_k}^2 \sum_{i=1}^{n}\left(\alpha_{j,i}\right)^2}{\sum_{j=1}^{k-1}\sum_{i=1}^{n} \sigma_{\varepsilon_j}^2\left(\alpha_{j,i}\right)^2} \tag{21}$$

We expect ambiguity to matter most during periods of crisis-induced turbulence and economic stress and that the relative effect of the *AMB* factor on banking risk should be more pronounced during the 2007-2009 crisis. More generally, the elicited ambiguity information should contribute to financial system instability through the above dynamics. This should be reflected in the relative variance proportions of $AMB^{banking}$ vis-à-vis other variables. The above should help validate whether investors and option holders' ambiguity behavior is associated with shifts in U.S. banking risk. For ease of exposition we use a principal component factor AMB^{PCA}, computed as the first component of AMB^{CU}, $AMB^{alpha\text{-}MEP}$ and AMB^{BI}, as our ambiguity proxy in the variance decomposition.

4. Empirical findings

This section presents our results along with descriptive statistics, correlation analysis, and the evolution of investors' ambiguity over the seven-year period 2003-2009. Through Eq. (19), we test whether $AMB^{banking}$ is a determinant of systemic risk beyond other standard option and market information. In line with H1, we verify if ambiguity from call and put prospects increases downside, systematic beta and credit risks. We test our hypotheses using daily and monthly data. For robustness, we verify if ambiguity from IYF (SPX) data is also positively associated with systemic banking risk. Our variance decomposition analysis (Eqs. (20-21)) further examines whether the effect of ambiguity on banking risk is more pronounced in times of crisis-induced turbulence, and to what degree ambiguity matters as a source of risk and financial instability (see H2). Implications for the real economy and findings on linkages between our ambiguity proxies and economic activity are covered in Section 4.3.

4.1. Descriptive statistics and correlations

Table 1 provides descriptive statistics and correlations for the explanatory variables used in our multivariate models in Eq. (19). $AMB^{banking}$ estimates for calls (and puts) are highly correlated (0.70 < ρ < 0.85) across periods and option moneyness levels.[10] This holds under both CU and α-MEP ambiguity specifications (Columns 5-7 for AMB^{CU} and Columns 9-11 for $AMB^{alpha\text{-}MEP}$). This corroborates the consistency of our measures of ambiguity and suggests that moneyness considerations may not cause major shifts in ambiguity perceptions in our banking investors' context. We also observe that under CU call-derived AMBs are negatively correlated with their put counterparts, suggesting that different CU preferences might exist among call and put option holders (Columns 5-6). Relatively lower correlations in ambiguity pessimism are also observed between $AMB^{alpha}{}_{calls}$ and $AMB^{alpha}{}_{puts}$ (Columns 9-10). As expected, we find that option-based AMB values are more pronounced (i.e., showing higher deviations from the Bayesian benchmark for both puts ($\overline{AMB^{CU}}$ = 0.35, $\overline{AMB^{alpha-MEP}}$ = 0.85) and calls ($\overline{AMB^{CU}}$ = 0.73, $\overline{AMB^{alpha-MEP}}$ = 0.92)) compared to risk-neutrality during 2007-2009 than in 2003-2009. The mean $AMB^{BI}{}_{IYF}$ score from IYF is also found to be higher in 2007-2009 ($\overline{AMB^{BI}}$ = 1.50) than in 2003-2009 ($\overline{AMB^{BI}}$ = 1.06). Further analysis suggests that during 2007-2009(10) put option holders were more ambiguous than during 2003-2006. Similarly, during 2007-2009(10) call option holders were more ambiguous than in 2003-2006. This underscores increasing uncertainty and potential disagreement among investors during our period of study.

The above confirms the presence of ambiguity among market investors, suggesting that partial ignorance, speculative behavior and fear of uncertainty might lie behind the surge in U.S. banking risk characterizing the 2007-2009 period. Figure 1 illustrates these dynamics, tracking systemic banks' market capitalization and banking investors' ambiguity behavior under CU (Figure 1a), α-MEP (Figure 1b) and EUUP (Figure 1c) from 2003 to 2010. The more turbulent 2007-2009 period (shaded area) is characterized by more severe losses in banks' market values. These patterns are accompanied by significant variations in ambiguity and higher ambiguity levels throughout the period. This suggests that fluctuations in systemic banking risk might be partly explained by variations in banking investors' ambiguity and severe behavioral deviations from Bayesian valuation and risk-neutrality.

[Insert Table 1 about here]

[10] Our AMB^{CU} indicators are highly correlated with two popular proxies for disagreement and uncertainty in economics: the University of Michigan Consumer Sentiment Index ($|\rho|$ > .64) and the macroeconomic uncertainty indicators ($|\rho|$ > .68) of Jurado et al. (2015), highlighting the relevance and reliability of our ambiguity measures and the weight of systemic banks in the U.S. economy. High absolute correlations are also obtained between $AMB^{alpha\text{-}mep}$ (AMB^{BI}) and the aforementioned proxies (.32 < $|\rho|$ < .71); the correlations are more positive for composite ambiguity scores $AMB^{CU}{}_{SUMDEV}$ and $AMB^{alpha}{}_{SUM}$ (.50 < $|\rho|$ < .81).

[Insert Figure 1 about here]

4.2. Multivariate findings

4.2.1. Daily regression results

Table 2 reports our base-case regression findings for 2003-2009 on the daily relationship between ambiguity and banking risk after controlling for standard market determinants. Herein, we use composite indicators of ambiguity (AMB^{CU}_{SUMDEV} and AMB^{alpha}_{SUM}), based on Eqs. (14) and (18), which capture deviations from Bayesian valuation for both calls and puts at the same time. Choquet-based AMB^{CU}_{SUMDEV} is the sum of absolute deviations of AMB_{puts} and AMB_{calls} from the unambiguous score of 0.5 and proxies for the overall level of ambiguity characterizing systemic banks in the options market. MEP-based AMB^{alpha}_{SUM} proxies for the overall degree of ambiguity pessimism in the (systemic) banking options market. For EUUP-based AMB^{BI}, and also for comparability with other composite indicators, we elicit ambiguity information from SPX to estimate the degree of ambiguity surrounding the S&P500 index. Our remaining tables (Tables 3-8) use AMB^{BI}_{IYF} inferred from IYF. In Table 2, Models 1-8 are concerned with downside risk (*DR*), Models 9-14 cover systematic risk (*EBETA*), and Models 15-23 examine credit risk (*CR*). We contrast OTM and ITM specifications without and with ambiguity. As EUUP-based AMB^{BI} uses comparable inputs and partly similar underlying information as *EBETA* in its calculation, causing multicollinearity and endogeneity, we do not report *EBETA* results for this ambiguity proxy. We find, however, that AMB^{BI} is positively associated with *CVaR* when the latter is used as alternative systemic banking risk proxy. In Table 2, AMB^{CU}_{SUMDEV} is positively associated with systemic banks' risk after controlling for other option-related information and market determinants. This holds for *DR* ($p < 0.01$), *EBETA* ($p < 0.01$) and *CR* ($p < 0.05$). Comparable conclusions are reached under α-MEP regarding *DR* ($p < 0.01$), *EBETA* ($p < 0.01$) and *CR* ($p < 0.05$). The only minor difference is OTM-based Model 19 where the $\mathrm{AMB}^{\mathrm{alpha}}_{\mathrm{SUM}}$-CR association is positive but insignificant. This is explained by the crash risk characteristics of OTM puts and the potential daily information overlap between put option-elicited AMB^{alpha} and *SDVIX*. When the latter is omitted from the regression, the $\mathrm{AMB}^{\mathrm{alpha}}_{\mathrm{SUM}}$-CR effect becomes positive and significant (Model 20, $p < 0.01$). Overall, we find that option-elicited ambiguity ($AMB^{banking}$) is positively associated with downside risk, systematic and credit risks. EUUP-based AMB^{BI}_{SPX} provides similar conclusions for *DR* and *CR* ($p < 0.01$). The above evidence supports our baseline hypothesis H1 on the positive effect of ambiguity on systemic banking risk and confirms that banking investors' subjective behavior, in the form of $AMB^{banking}$, was a significant determinant of banking risk during the 2003-2009 period. This pattern is also observed in our panel regressions on the effect of ambiguity per bank ($AMB^{CU,B}_{SUMDEV}$ and $AMB^{alpha,B}_{SUM}$) on systemic bank risk (see supplementary Table

S1).[11] Our supplementary findings in Table S2 confirm that the positive association between ambiguity ($AMB^{BI}{}_{SPX}$), elicited using SPX data over the 1999-2015 period, and systemic banking risk holds for longer time-windows. We find this effect to be more significant during NBER recessions.

[Insert Table 2 about here]

Overall period

Primarily concerned with $AMB^{banking}{}_{calls}$ and $AMB^{banking}{}_{puts}$, Tables 3-5 examine similar effects as in Table 2 for *DR*, *EBETA* and *CR* but differentiate between call and put transactions over 2003-2009, 2003-2006 and 2007-2009. AMB^{CU}-DR and AMB^{CU}-CR effects are reported in Tables 3 and 5 (Panels A), while Panels B of Tables 3 and 5 present α-MEP and AMB^{BI} results. Table 4 summarizes systematic risk *EBETA* findings for AMB^{CU} and $AMB^{alpha\text{-}MEP}$ only. This is due to the aforementioned measurement and input characteristics of the AMB^{BI} proxy, which this time is elicited from IYF data for consistency with the call/put-specific banking scores covered in Tables 3-5. The 2003-2009 sample results (Tables 3-5: Models 1-4, and Models 1-6 in Table 4) are in line with those documented in Table 2. Significant improvements in Adj. R^2 are observed when comparing AMB-based specifications against those without ambiguity. $AMB^{banking}$ is positively (negatively) associated with systemic banks' risk (performance). This holds for both call and put option transactions. Under CU, ambiguity from calls ($AMB^{CU}{}_{calls}$) is significantly positively associated with downside, credit and systematic risks (Tables 3-5: Overall Period) after controlling for *IV*, *SKEW*, *OI* and *SDVIX*. For puts, ambiguity ($AMB^{CU}{}_{puts}$) is similarly positively associated with *DR* (Table 3 Panel A), *EBETA* (Table 4) and *CR* (Table 5 Panel A) after controlling for other option-based market factors ($p < 0.05$).[12] Similar patterns are observed under α-MEP in Panels B of Tables 3 and 5, and in Table 4. $AMB^{alpha}{}_{calls}$ is positively associated with *DR* ($p < .01$), *EBETA* ($p < .01$) and *CR* ($p < .05$). The same holds for $AMB^{alpha}{}_{puts}$ for *DR* ($p < .01$) and *EBETA* ($p < .01$) (Table 3 Panel B and Table 4). For *CR*, positive but sometimes marginally significant associations are observed in Table 5 Panel B (Models 1-2: Puts). In line with Table 2, the significance of $AMB^{alpha}{}_{puts}$ is reestablished in the *CR* regressions when *SDVIX* is omitted from the puts-based information structure. This is once again explained by daily information overlap caused by the volatility of volatility proxy. Moreover, we find the AMB^{alpha}-CR effect to be positive and significant when *DD* is used as an alternative CR proxy (unreported). The above results confirm that positive changes in ambiguity are associated with negative shifts in systemic banking performance. Panels B of

[11] Our panel regression findings also hold when using CVaR and Merton's distance-to-default measure as alternative proxies for systemic bank risk. As the panel regression analysis is firm-specific, LIBOR-related specifications are not applicable.
[12] Under CU, ambiguity aversion declines with an increasing AMB^{CU} score, so a negative coefficient on $AMB^{CU,banking}$ in Eq. (19) implies a positive effect of ambiguity on banking risk.

Tables 3 and 5 provide similar conclusions under EUUP using the AMB^{BI}_{IYF} score ($p < .01$). These patterns are again confirmed in our panel regressions on the effect of AMB^{B} on systemic bank risk (see supplementary Table S1). This corroborates Hypothesis 1. Our conclusions tend to hold after controlling for NBER recessions.

[Insert Tables 3-5 about here]

Stable period

Tables 3-5 also contrast the more stable (2003-2006) period to the later turbulent crisis period (2007-2009) using daily data. Models 5-12 (7-18) in Tables 3 and 5 (Table 4) present related results based on Eq. (19), examining the daily dynamics of the various $AMB^{banking}$ indicators for calls and puts, respectively, after controlling for option-based *IV*, *SKEW*, *OI* and *SDVIX*. The 2003-2006 stable period findings (Models 5-8 in Tables 3 and 5, and Models 7-12 in Table 4) confirm that *IV* was a significant determinant of systemic risk for puts and calls as documented in previous literature (e.g., Swidler and Wilcox, 2002). This is in line with our base-case regressions in Table 2 and findings from Models 1-4 (1-6) in Tables 3 and 5 (Table 4). In accord with Friesen et al. (2012), the SKEW index is negatively associated with *DR*, *EBETA* and *CR*. *OI* is negatively correlated with *DR* (Table 3 Panels A and B), but not with systematic and credit risks (Tables 4-5). Volatility of volatility, capturing "unk-unk" dynamics, is negatively (positively) associated with downside and credit risks during 2003-2006 (2003-2009: Models 1-4). $AMB^{banking}$ elicited from calls and puts - under both CU and α-MEP - is generally not a consistently significant determinant of downside risk during the more stable period 2003-2006 (Table 3 Panels A and B: Stable Period), suggesting that downside risk considerations are likely to be more relevant during uncertain market trading periods. An interesting finding is that AMB^{BI}, which captures the degree of probabilistic ambiguity in IYF, is negatively associated with downside risk in 2003-2006. This might be due to the less robust lead-lag dynamics (compared to options markets) between ETF markets and underlying counterparts, and the tracking features of ETF investments. AMBs provide some incremental information to the *EBETA* (Table 4) and *CR* regressions (Table 5 Panels A and B), indicating that investor ambiguity was already contributing to significant changes in systemic banks' risk prior to the 2007-2009 crisis. Option-related AMBs (CU- and α-MEP-based) tend to have positive associations with systematic and credit risks after controlling for other effects during the stable (2003-2006) period (Table 4: Models 7-12, and Table 5: Models 5-8). In line with *DR* results, EUUP-based AMB^{BI} once again shows a negative effect on *CR* during this stable period. In general, however, we find that there is less pronounced evidence of ambiguity behavior among investors during this period.

Uncertain period

By contrast, during the crisis period of 2007-2009 when ambiguity is more prevalent (Tables 3 and 5: Models 9-12, and Models 13-18 in Table 4), we find that after controlling for other effects and relevant daily market factors, AMBs are consistently highly significant adding important incremental information and explanatory power (higher adj. R^2) in line with our predictions (Tables 3-5: Uncertain Period). Higher and more significant coefficients for all $AMB^{banking}$ proxies are also observed throughout. $AMB^{banking}$ from call options (AMB_{calls}) has a significant positive effect on banks' *DR* ($p < 0.05$) (Table 3 Panels A and B: Models 9-12), *EBETA* ($p < 0.01$) (Table 4: Models 13-18) and *CR* ($p < 0.05$) (Table 5 Panels A and B: Models 9-12) during the turbulent 2007-2009 period. This provides support for Hypothesis 2 on the moderating role of economic uncertainty in the relationship between ambiguity and systemic banking risk. CU results suggest that, due to higher ambiguity (higher $AMB^{CU,banking}$ scores), call option positions on major U.S. banking stocks might have been subject to speculation and erratic behavior during the 2007-2009 recession and its aftermath (downside market and crisis-induced turbulence). For put option holders, we confirm that under CU ambiguity (AMB^{CU}_{puts}) had a significant positive effect on downside ($p < 0.05$), systematic (market beta) ($p < 0.01$) and credit risks ($p < 0.05$). This provides further support for H2 and implies that higher ambiguity from puts (i.e., lower $AMB^{CU,banking}$ scores and higher distance from the benchmark value of 0.5), with possibly higher demand for self-insurance, was associated with higher banking risk (Tables 3-5 Panels A and Table 4). Table 4 and Panels B of Tables 3 and 5 generally corroborate these findings for α-MEP and EUUP-based AMB^{BI}. AMB^{alpha}_{calls} is significantly positively associated with *DR* ($p < 0.05$), *EBETA* ($p < 0.01$) and *CR* ($p < 0.05$). For puts, AMB^{alpha}_{puts} have positive effects on *DR* ($t = 1.752$, $p = .080$), *EBETA* ($p < 0.01$) and *CR* ($p < 0.05$) (after omitting *SDVIX* from OTM-based CR Model 9). The same conclusions hold for AMB^{BI}_{IYF} regarding downside risk and credit risk ($p < 0.01$). Similar results are obtained for DD and CVaR (unreported). The above underscores the role of ambiguity in call and put option transactions and shows that investor subjective behavior can induce adverse effects on banking performance during periods when markets are fraught with uncertainty. Overall, ambiguity ($AMB^{banking}$) from banking equity options markets has exacerbated the level of risk present in the U.S. banking system during the 2007-2009 period. This finding is robust to alternative specifications of ambiguity. It also empirically validates recent theoretical insights by Dicks and Fulghieri (2019) on uncertainty aversion and systemic risk.

Similar outcomes are obtained when examining the effects of the composite systemic indicators of ambiguity ($AMB^{CU,banking}_{SUMDEV}$ and $AMB^{alpha.banking}_{SUM}$) over 2007-2009 (unreported). Our results are further robust to option moneyness differences and to using volatility rather than price as an input for *AMB* estimation. Using the Merton distance-to-default measure as an alternative proxy for credit risk also does not alter our conclusions on the adverse effect of ambiguity on systemic bank risk.

In terms of transmission mechanisms, we find using variance decomposition that ambiguity affects systemic banking risk (via *m* and *s* in CU and *m* only under MEP) through all valuation channels (r, δ, μ and σ) and that no single factor unequivocally dominates.[13] While the diffusion channel plays a non-negligible role under CU in uncertain times, it does not drive our results (verified using a residual-based *AMB* after regressing AMB^{CU} on volatility). The same holds for other channels. Consistent residual-based findings are also obtained under α-MEP and EUUP (i.e., no single factor dominates). Ambiguity should affect the various channels non-linearly (see Eq. (1)).

[Insert Table 6 about here]

4.2.2. Monthly regression results

For robustness, we repeat the analysis using monthly data for the 2003-2009 period. Table 6 presents our monthly regression results summarizing the effect of the $AMB^{CU,banking}$ indicators on systemic bank risk for call, put and overall options transactions (Models 3-6, 9-12 and 15-18). Models 1-6 cover downside risk (*DR*), Models 7-12 examine systematic beta risk (*EBETA*) and Models 13-18 are concerned with credit risk (*CR*). Given that ambiguity behavior should be more prevalent in higher frequency data, the predictive powers of the monthly AMBs are not always as high as in the daily counterparts. Despite this, our predictions also hold using monthly data. Results confirm that, after controlling for implied volatility, skewness, option market liquidity and volatility of volatility dynamics, higher ambiguity ($AMB^{banking}{}_{puts}$) is generally associated with higher banking risk for put contracts (Models 3-4, 9-10 and 15-16). For call options, ambiguity ($AMB^{banking}{}_{calls}$) has a significant positive effect on *DR*, *EBETA* and *CR* (Models 3-4, 9-10 and 15-16). This holds even after controlling for crisis effects (with a dummy variable). We find similar patterns for the composite indicator of ambiguity $AMB^{CU}{}_{SUMDEV}$ (Models 5-6, 11-12 and 17-18). Supplementary Table S3 presents results for the α-MEP and EUUP specifications. Findings are consistent throughout and robust to these two alternative ambiguity specifications (in line with Tables 2-6). These monthly results validate our previous daily findings, suggesting that ambiguity-related deviations from Bayesian valuation and risk-neutrality were associated with the sharp shifts in risk that occurred in the U.S. banking sector during 2003-2009 (with such adverse effects lasting at least up to one month). These findings again validate our predictions based on Eqs. (2-6) and our hypotheses.

[13] For example over 2003-2009, we find that under CU the proportion of *DR* (*EBETA*) variance explained by r' (δ') is on average higher than the proportions of variance explained by $s\sigma$ and δ'($s\sigma$ and r'). On the other hand, the proportion of *CR* variance explained by $s\sigma$ is, on average, higher than the proportions explained by r' and δ'. For MEU, r' and σ explain *CR* variance better than δ' while the latter explains *EBETA* better than former two. Additionally, we find no major differences in variance proportions explained by adjustment factors *m* and *s* vis-à-vis systemic banking risk under CU.

We conclude that ambiguity ($AMB^{banking}$) has been a significant determinant of systemic risk in the U.S. over our period of study.

[Insert Table 7 about here]

4.2.3. Variance decomposition results

This section presents our variance decomposition results on how investor ambiguity dynamics compare across low vs. high uncertainty regimes and further examines feedback effects among the different variables used in our regressions. As mentioned, we use the first principal component (AMB^{PCA}) of $AMB^{CU,banking}$, $AMB^{alpha,banking}$ and $AMB^{BI}{}_{IYF}$ as our ambiguity proxy herein. Our predictions based on Eqs. (20-21) and H2 suggest that the relative effect of ambiguity on systemic banking risk should be more pronounced during periods of high uncertainty and economic stress. Table 7 (Panels A-C) presents our daily variance decomposition results for the stable period 2003-2006 vs. the more uncertain 2007-2009 period. Each entry in the tables denotes the percentage of forecast error variance of variables on the left-hand side explained by the variables at the top (using average moneyness). Entries converge in a 250-day horizon. The tables show that the proportion of banking risk variance that can be explained by its own shock generally declines during the crisis. This indicates that shocks from other variables, in particular AMB^{PCA} and *IV*, are more prominent in explaining banking risk during the crisis than before. More importantly, we find that the proportions of *DR* (Table 7 Panel A: Columns 3 & 9), *EBETA* (Table 7 Panel B: Columns 3 & 9) and *CR* (Table 7 Panel C: Columns 3 & 9) variances explained by AMB^{PCA} increase significantly during the crisis compared to the more stable 2003-2006 period, and that ambiguity behavior is a leading source of systemic risk in the U.S. banking system during 2007-2009. This holds for both put and call transactions.[14] On average, *AMB* from calls explains around 10% of systemic banking risk variance during 2007-2009 vs. only 2% over 2003-2006. For put options, *AMB* on average explains 7.5% of banking risk variance during the crisis vs. 0.48% in the earlier stable period. *AMB* from puts is the most important "external" source of credit risk during the crisis. Given the context of the 2007-2009 recession, this is not surprising. The above validates and corroborates hypothesis H2. Finally, AMB^{PCA} seems to influence, and tends to be influenced by, more variables during the crisis than previously, highlighting the presence of feedback loops/effects across the banking industry and increasing risk and financial instability. The above confirms that ambiguity is an important source of systemic banking risk in the U.S. and that tracking and monitoring the subjective behavior of investors can help detect or anticipate signs of banking stress, downside performance, and

[14] Most of these results hold under each ambiguity specification. Similar to the sub-sections covering our multivariate regression results, the 2003-2009 variance decomposition findings for *AMB* were in line with their 2007-2009 counterparts.

instability. In sum, ambiguity matters greatly in the marketplace especially in times of crisis-induced turbulence and heightened financial uncertainty.

The next section summarizes implications for the real economy and provides additional empirical evidence on the negative effect of ambiguity on economic outcomes. As market-elicited ambiguity is positively related to systemic banks' risk and increases financial system instability, our $AMB^{banking}$ indicators should have negative repercussions on the real economy and influence corporate policy.

4.3. Economic activity implications

Monthly univariate regressions are implemented to test the *lagged* association between investors' ambiguity $AMB^{banking}$ and economic activity. To gain additional insights into the linkages between financial markets, the banking sector and the real economy, we also examine the effect of systemic banking risk (*SBR*) on real economic activity indicators (i.e., accounting for potential endogeneity). Our analysis involves the use of monthly $AMB^{banking}$ and *SBR* data as explanatory variables. Economic activity indicators serving as our dependent variables, therefore, consist of: capacity utilization growth (*CUG*) measuring monthly industrial production, total non-farm payroll growth (*TNPG*) as an indicator of monthly employment, and changes in the Chicago Fed National Activity Index (*CFNAI*) as a proxy for overall economic performance on a monthly basis. Table 8 (Panels A-C) summarizes our results.

Table 8 Panel A presents findings on the real economy implications of ambiguity under CU, while Panel B reports AMB^{alpha} and AMB^{BI}_{IYF} results. Panel C summarizes systemic banking risk effects specific to CU. Table S4 reports *SBR* findings under α-MEP and EUUP. All $AMB^{banking}$ indicators in Panel A are found to be negatively associated with economic activity, confirming that ambiguity has adverse effects on the real economy. Capacity utilization, total non-farm payrolls and the CFNAI all decrease with increasing ambiguity. Call option-elicited ambiguity $AMB^{CU,banking}_{calls}$ has a negative effect on industrial production ($p < 0.05$), hiring ($p < 0.05$) and overall economic output ($p < 0.01$). Higher (lower) ambiguity from puts $AMB^{CU,banking}_{puts}$ is also negatively (positively) associated with real activity ($p < 0.01$). Finally, AMB^{CU}_{SUMDEV} (proxying for the overall degree of ambiguity in the systemic banking option market) shows consistently significantly negative effects on *CUG*, *TNPG* and the *CFNAI* ($p < 0.01$). Our results are robust to the α-MEP and EUUP ambiguity specifications (Panel B). These findings are in line with economic theory predictions on the negative role of uncertainty in real economic activity (e.g., real options, precautionary saving and financial frictions arguments) and accord with recent macro evidence by Berger et al. (2017) and Berger and Sedunov (2017) on linkages among economic policy uncertainty, bank liquidity creation and real economic output. Our results suggest that measures and policies reducing the level of subjective behavior and ambiguity in the financial markets can help to enhance aggregate economic activity.

Panel C reports our systemic banking risk (*SBR*) results under CU. We use both direct (raw) measures of systemic banking risk (*DR, EBETA* and *CR*) and predicted *SBR* measures (based on Eq. (19)). For robustness and to mitigate endogeneity concerns (see e.g., Berger and Bouwman, 2013),[15] we also verify that our main results hold under GMM using an instrumental approach. Findings confirm that systemic banking risk is consistently negatively associated with the three important aspects of economic activity we consider. Industrial production, hiring and overall economic output all decrease with higher systemic banking risk. An interesting finding is that, in most regression cases under CU (except for *DR* as a predictor of *CUG*), the predicted *SBR* measures display more negative coefficients than their raw counterparts. Supplementary Tables S4 and S5 display comparable patterns. This suggests that the determinants of systemic banking risk (including $AMB^{banking}$), and the associated feedback loops, might be more important in depressing economic activity than *SBR* itself. *SBR* might, thus, serve as a "medium" between the financial markets and the real economy. This is in line with research by Bartram et al. (2007) on the measurement and role of systemic risk in the global financial system.

Overall, our above findings confirm that ambiguity, measured under CU, α-MEP and EUUP, can depress real economic activity and influence corporate policy. Such an adverse effect is mostly reflected in industrial production, employment and aggregate economic performance. This additional evidence underscores the weight of systemic banks in the economy, the role of subjective behavior and cognitive limitations in the operations of financial markets, and the detrimental effect of investors' ambiguity biases on the financial system and the real economy. Importantly, we document that ambiguity from the financial markets and systemic banking risk did bring losses to the US economy during the 2003-2009 period.

[Insert Table 8 about here]

5. Discussion and conclusions

This paper provides evidence on the consequences of investors' subjective behavior in the financial markets concerning the prospects of too-big-to-fail U.S. banks over the period 2003-2009. We learn that the financial options market is characterized by ambiguity when it comes to transactions involving systemic banks, with ambiguity behavior found in both put and call options instruments. This behavior is more prevalent in times of downside markets

[15] The Hausman endogeneity test confirmed the presence of endogeneity bias in the SBR-economic activity regressions. Supplementary Table S5 reports GMM estimation results for this relationship using *AMB* and *SKEW* as instruments. Our GMM results corroborate our CU-based findings (and those under α-MEP and EUUP, unreported).

and financial crises. As a result of valuation biases, suboptimal option exercise and erroneous trades, ambiguity elicited from option pricing transactions is found to increase banks' downside risk, systematic risk, and credit risk. This holds in calls and put options markets and also when ambiguity is elicited from the IYF ETF and SPX data. The positive relationship between investor ambiguity and systemic banking risk is moderated by economic uncertainty. We also confirm that distortions arising from subjective behavior, in the form of $AMB^{banking}$, in the financial markets can bring losses to the real economy and have adverse effects on economic activity.

The above adds to extant literature on the role of deviating behavior and cognition in financial services and markets by examining the case of 'sophisticated' investors, unveiling the consequences of their ambiguity on the banking sector and the real economy. The paper also supplements extant experimental research on how ambiguity biases affect pricing dynamics and investment decisions in the presence of high uncertainty. We provide evidence of ambiguity effects in a natural market setting. Our study also relates to existing behavioral research in management on ambiguity and firm/industry performance (e.g., King and Zeithaml, 2001; Powell et al., 2006; Friberg and Seiler, 2017) by highlighting how subjective behavior in the marketplace can have negative repercussions on financial system stability and systemic banking performance. We find that higher ambiguity among call and put option holders is associated with higher (lower) systemic bank risk (performance), and higher ambiguity from ETFs increases financial sector instability.

In terms of practical implications, we propose simple indicators of uncertainty for systemic banking to gauge changing ambiguity behavior among investors over time. Eliciting investors' ambiguity (pessimism) information directly from call and put option prices on major U.S. banks' stocks, we are able to provide clear evidence of subjective behavior in banking equity derivatives markets and, consequently, shed light on the effects of investors' biases and limited information processing around banking crises. At the policy level, our findings call for more robust monitoring of investment behavior, especially around times of banking instability (bubbles, crashes and crises), and underscore the need to incorporate behavioral economics principles in financial institutions' financial management, planning and supervision. In terms of broader regulation, banking performance and risk management implications, our indicators of banking uncertainty and investor ambiguity can be used by bank managers as early warning signals for monitoring banking risk exposures and gauging investors' behavior under different uncertainty regimes. Our ambiguity scores (AMB^{B} and $AMB^{banking}$) might also serve as additional proxies for systematic turbulence and Knightian uncertainty in the marketplace, and as advanced warning signs of impending problems in the real economy.

Further research is warranted on the role and contribution of ambiguity in understanding firm performance and global financial markets, and its potential interactions with disagreement and sentiment effects. The impact of ambiguity on stock returns and other performance indicators can be examined under different data specifications (e.g., intraday or weekly) or using alternative behavioral frameworks. Ambiguity also affects corporate decisions and can be elicited from managerial reports, fundamental accounting information and mergers and acquisitions transactions. Studying the determinants of ambiguity (and its implications) in these various settings and contexts, and linking antecedents and outcomes to corporate governance and sustainability matters should generate fruitful avenues for future research.

APPENDIX

Appendix A. The role of ambiguity in option valuation

No ambiguity:

The price of the underlying bank stock S, on which the option contract is written, follows a singleton-based Brownian motion (e.g., Black and Scholes, 1973; Merton, 1973) of the form:

$$\frac{dS}{S} = \mu dt + \sigma dz \qquad \text{(A1)}$$

Because of indifference towards uncertainty, uniformity in model specification and market completeness, the fundamental equation to value options under risk-neutrality (with dividend yield δ) is as follows:

$$\frac{\partial O}{\partial t} + S^2 \frac{1}{2}\frac{\partial^2 O}{\partial S^2}\sigma^2 + (r-\delta)\frac{\partial O}{\partial S}S - rO = 0 \qquad \text{(A2)}$$

The well-known BSM formula, without ambiguity adjustments, is a solution to Eq. (A2). For call options:

$$O = S_0 e^{-\delta T} N(d_1) - X e^{-rT} N(d_2) \qquad \text{(A2.1)}$$

where:

$$d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r - \delta + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} \text{ and } d_2 = d_1 - \sigma\sqrt{T}$$

Choquet ambiguity:

The price of the underlying stock S follows the ambiguity-based Choquet (set of) Brownian motion(s), or so-called symmetric Choquet random walk, of the form (see e.g., Kast and Lapied, 2010; Agliardi et al., 2016):

$$\frac{dS}{S} = (\mu + m\sigma)dt + s\sigma dz \qquad (\forall\, m \in]-1,1[\;, \forall\, s \in]0,1]) \qquad \text{(A3)}$$

Due to uncertainty in model specification and a lack of complete information about the future realizations of market returns and volatility (i.e., multiple distributions), m and s alter investors' valuation, trading and option exercise decisions. $m = 2c-1$ and $s^2 = 4c(1-c)$, where c is the ambiguity score (with $0 < c < 1$) indicative of investors' ambiguity perceptions. Eq. (A3) has been shown to subsume alternative ambiguity frameworks from the multiple priors (MEP) family where $m \neq 0$ and $s = 1$. Appendix B covers some of the main properties of the above (symmetric) Choquet random walk.

Eq. (1), in Section 2.1.1, is the fundamental equation to value options under A3 (with dividend yield δ). As solutions to Eq. (1), Eqs. (2-3) are ambiguity-based versions of the BSM formulae under CU. When $m = 0$ and $s = 1$ (i.e., no ambiguity), Eq. (A3) simplifies to A1 and Eqs. (2-3) revert back to the standard BSM ($c = 0.5$ and A2.1).

Multiple priors ambiguity:

The price of the underlying stock S, on which the option contract is written, follows the ambiguity-based multiple priors (set of) Brownian motion(s) of the form:

$$\frac{dS}{S} = (\mu + m\sigma)dt + \sigma dz \qquad (\forall\, m \in]-1,1[) \qquad \text{(A4)}$$

Due to uncertainty in model specification and a lack of complete information about the future realizations of market returns, $-1 < m < 1$ alters investors' valuation, trading and option exercise decisions through the drift component of the Brownian motion. A4 is a special case of A3. The fundamental equation to value options under A4 is nested in Eq. (1) ($s = 1$ case). Similarly, Eqs (2-3) in Section 2.1.1 subsume the multiple priors versions of the BSM formulae.

Appendix B. Symmetric Choquet random walk (based on Kast and Lapied (2010))

Following Kast and Lapied (2010) and Kast et al. (2014), consider any node n_t at date t ($0 \leq t \leq T$) and its possible up or down successors next period n_{t+1}^{u} and n_{t+1}^{d} (following an "up" or a "down" move, respectively) in a dynamic binomial tree. The Choquet random walk is defined by a conditional capacity c (rather than additive probabilities) which has the same magnitude of an "up" or "down" move from one period to the next such that:

$$v(n_{t+1}^{u}/n_t) = v\left(n_{t+1}^{d}/n_t\right) = c \text{, with } 0 < c < 1 \tag{B1}$$

Capacity variable c captures the ambiguous weight or distortion in probabilities and summarizes investor ambiguity perceptions. The Choquet integral is employed to obtain the subjective expected value of the underlying asset price with respect to the specific weighted function v or constant capacity c. The decision weights used in the computation of the Choquet integral will overweight high outcomes if the capacity is more concave (increasing ambiguity under ambiguity-seeking) and favor low outcomes if the capacity is more convex (increasing ambiguity for ambiguity aversion), relative to the Bayesian probabilistic case $c = ½$.

Consider a random process: $X = (X_t)_{t \in T}$, with random variables X_t and Y_t. Let $Y_t = X_{t+1} - X_t$, where Y_t takes the value 1 with capacity c and -1 with capacity $1-c$. Satisfying the properties of the symmetric random walk by Kast and Lapied (2010) and Kast et al. (2014), $E(Y_t) = 2c - 1 = m$, $Var[Y_t] = 4c(1-c) = s^2$. The resulting random walk converges in continuous-time to a general Wiener process with mean m and variance s^2. Define a discrete-time process W_t by: $W_t = mh + s\sqrt{h}U_t$, where U_t takes the value 1 with probability 1/2 and -1 with probability 1/2. Then $E(W_t) = m$ and $Var(W_t) = s^2$. The resulting Brownian motion, thus, has a distorted mean and distorted variance that are functions of ambiguity score c (i.e., A3). The standard Wiener process with mean zero and variance of 1 (i.e., c = ½) is in A1.

Appendix C. Control variables

Implied Volatility (IV). The Black-Scholes model (1973) is employed to back-out *IV* per bank as follows:

$$IV_{t,T}^{B} = BSM^{-1}(X, S_t^B, T, r_t, \delta_t^B) \tag{C1}$$

where BSM^{-1} stands for the inverse of the Black-Scholes function in A2.1. From this, the weighted average implied volatility for the set of banks examined is calculated as follows:

$$IV_{t,T}^{banking} = \sum_i w_i \, IV_{t,T}^{B} \tag{C2}$$

Option Market Liquidity (OI). This is aggregated open-interest computed by taking the sum of open-interest for all out-of-the-money (OTM) and in-the-money (ITM) call and put contracts. For example, the open-interest for OTM calls is:

$$OI_t^{OTM\ call,banking} = \sum_i \sum_j OI_t^{OTM\ call,B} \tag{C3}$$

where $OI_t^{OTM\ call}$ is the open interest of out-of-the-money calls at time t, i is the index for bank B and j is the number of out-of-the-money call option contracts.

Volatility of Volatility (SDVIX). This is computed as the annualized standard deviation of daily changes in VIX based on a 22-day moving estimation window:

$$SDVIX_t = \sqrt{\sum_{i=1}^{22} \frac{\left(r_{t+1-i}^{VIX} - \overline{r_{t,t-22}^{VIX}}\right)^2}{N-1} \times 252} \quad \text{(C4)}$$

where $SDVIX_t$ is the volatility of VIX on day *t*, r_t^{VIX} is the logarithmic change of the VIX index on day t and $\overline{r_{t,t-22}^{VIX}}$ is the average logarithmic change of the VIX over the last 22 trading days.

Skewness (*SKEW*). Capturing tail risk and risk information not contained in VIX, *SKEW* is obtained from the CBOE through the SKEW index.

REFERENCES

Abdellaoui, M., Vossman, F., & Webber, M., 2005. Choice-Based Elicitation and Decomposition of Decision Weights for Gains and Losses under Uncertainty. Management Science 51, 1384-1399.

Abdellaoui, M., Baillon, A., Placido, L., & Wakker, P.P., 2011. The Rich Domain of Uncertainty: Source Functions and Their Experimental Implementation. American Economic Review 101, 679-723.

Agliardi, E., Agliardi, R., & Spanjers, W., 2016. Corporate financing decisions under ambiguity: Pecking order and liquidity policy implications. Journal of Business Research 69, 6012-6020.

Agliardi, R., 2017. Asymmetric Choquet random walks and ambiguity aversion or seeking. Theory and Decision 83, 591-602.

Alary, D., Gollier, C., & Treich, N., 2013. The effect of ambiguity aversion on insurance and self-protection. Economic Journal 123, 1188-1202.

Alessandri, P., Nelson, B.D., 2015. Simple banking: Profitability and the yield curve. Journal of Money, Credit and Banking 47, 143-175.

Alexander, C., 2001. Mastering Risk. London: FT-Prentice Hall.

Allais, M., 1953. Le comportement de l'homme rationnel devant le risqué. Econometrica 21, 503-546.

Andrews, D.W.K., 1991. Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimation. Econometrica 59, 817-858.

Arnold, T., Fishe, R.P.H., & North, D., 2010. The effects of ambiguous information on initial and subsequent IPO returns. Financial Management 39, 1497-1519.

Artinger, S., Powell, T.C., 2016. Entrepreneurial failure: Statistical and psychological explanations. Strategic Management Journal 37, 1047-1064.

Baillon, A., Bleichrodt, H., Keskin, U., l'Haridon, O., & Li, C., 2017. The effect of learning on ambiguity attitudes. Management Science 64, 2181-2198.

Baillon, A., L'Haridon, O., 2016. La decision en ambiguïté: Modèles et évaluations expérimentales. L'Actualité Economique 92, 81–111.

Baker, M., Wurgler, J., 2006. Investment Sentiment and the Cross-Section of Stock Returns. Journal of Finance 61, 1645-1680.

Baker, S.D., Hollifield, B., & Osambela, E., 2016. Disagreement, speculation and aggregate investment. Journal of Financial Economics 119, 210-225.

Bargeron, L.L., Lehn, K., Moeller, S.B., & Schlingemann, F.P., 2014. Disagreement and the informativeness of stock returns: The case of acquisition announcements. Journal of Corporate Finance 25, 155-172.

Bartram, S.M., Brown, G.M., & Hund, J.E., 2007. Estimating systemic risk in the international financial system. Journal of Financial Economics 86, 835-869.

Basak, S., 2000. A model of dynamic equilibrium asset pricing with heterogeneous beliefs and extraneous risk. Journal of Economic Dynamics and Control 24, 63-95.

Bekaert, G., Hoerova, M., 2014. The VIX, the variance premium and stock market volatility. Journal of Econometrics 183,181-192.

Berger, A.N., Bouwman, C.H.S., 2013. How does capital affect bank performance during financial crises?. Journal of Financial Economics 109, 146-176.

Berger, A.N., Guedhami, O., Kim, H.H., & Li, X., 2017. Economic policy uncertainty and bank liquidity creation. Working Paper, Darla Moore School of Business.

Berger, A.N., Sedunov, J., 2017. Bank liquidity creation and real economic output. Journal of Banking & Finance 81, 1-19.

Bilinski, P., Cumming, D.J., Hass, L., Stathopoulos, K., & Walker, M., 2019. Strategic distortions in analyst forecasts in the presence of short-term institutional investors. Accounting and Business Research 49, 305-341.

Black, F., Scholes, M., 1973. The pricing of options and corporate liabilities. Journal of Political Economy 81, 637–654.

Borochin, P., Yang, J., 2017. Options, equity risks, and the value of capital structure adjustments. Journal of Corporate Finance 42, 150-178.

Boyarchenko, N., 2012. Ambiguity shifts and the 2007-2008 crisis. Journal of Monetary Economics 59, 493-507.

Boyarchenko, S., Levendorskii, S., 2007. Practical guide to real options in discrete time. International Economic Review 48, 311-342.

Brenner, M., Izhakian, Y., 2018. Asset pricing and ambiguity: Empirical evidence. Journal of Financial Economics 130, 503-531.

Brown, C., Hao, C., 2012. Treating uncertainty as risk: The credit default swap and the paradox of derivatives. Journal of Economic Issues 46, 303–312.

Bruce, A., Skovoroda, R., 2013. Bankers' bonuses and the financial crisis: Context, evidence and the rhetoric-policy gap. Business History 55, 139-160.

Bushman, R.M., Davidson, R.H., Dey, A., & Smith, A., 2018. Bank CEO materialism: Risk controls, culture and tail risk. Journal of Accounting and Economics 65, 191-220.

Cao, H.H, Wang, T., & Zhang, H.H., 2005. Model uncertainty, limited market participation and asset prices. Review of Financial Studies 18, 1219-1251.

Carson, S.J., Madhok, A., & Wu, T., 2006. Uncertainty, Opportunism, and Governance: The Effects of Volatility and Ambiguity on Formal and Relational Contracting. Academy of Management Journal 49, 1058-1077.

Chateauneuf, A., Kast, R., & Lapied, A., 2001. Conditioning capacities and Choquet integrals: The role of comonotony. Theory and Decision 51, 367-386.

Chateauneuf, A., Eichberger, J., & Grant, S., 2007. Choice under uncertainty with the best and worst in mind: Neo-additive capacities. Journal of Economic Theory 137, 538-567.

Chen, Y-W., Chen, S-S., & Chou, R.K., 2019. Short-Sale Constraints and Option Trading: Evidence from Reg SHO. Journal of Financial and Quantitative Analysis, forthcoming.

Christensen, B.J., Prabhala, N.R., 1998. The relation between implied and realized volatility. Journal of Financial Economics. 50, 125-150.

Coff, R., Laverty, K., 2007. Real options meet organizational theory: coping with path dependencies, agency costs and organizational form. Advances in Strategic Management 24, 333-361.

Cording, M., Christmann, P., & King, D.R., 2008. Reducing Causal Ambiguity in Acquisition Integration: Intermediate Goals as Mediators of Integration Decisions and Acquisition Performance. Academy of Management Journal 51, 744-767.

Cremers, M., Weinbaum, D., 2010. Deviations from put-call parity and stock return predictability. Journal of Financial and Quantitative Analysis 45, 335-367.

Cumming, D.J., Johan, S., & Peter, R., 2018. Developments in financial institutions, governance, agency costs, and misconduct. Journal of International Financial Markets, Institutions and Money 54, 1-14.

Cyert, R., March, J.G., 1963. A Behavioral Theory of the Firm. NJ: FT-Prentice Hall.

Dicks, D.L., Fulghieri, P., 2019. Uncertainty aversion and systemic risk. Journal of Political Economy 127, 1118-1155.

Dow, J., Werlang, S., 1992. Uncertainty aversion, risk aversion and the optimal choice of portfolio. Econometrica 60, 197-204.

Driouchi, T., Trigeorgis, L., & So, H.Y., 2018. Option implied ambiguity and its information content: Evidence from the subprime crisis. Annals of Operations Research 262, 463-491.

Driscoll, J.C., Kraay, A.C., 1998. Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data. Review of Economics and Statistics 80, 549-560.

Dumas, B., Lewis, K.K., & Osambela, E., 2016. Differences of Opinion and International Equity Markets. Review of Financial Studies 30, 750-800.

Dunning, D., Meyerowitz, J.A., & Holzberg, A.D., 1989. Ambiguity and self-evaluation: The role of idiosyncratic trait definitions in self-serving appraisals of ability. Journal of Personality and Social Psychology 57, 1082-1090.

Easley, D., O'Hara, M., 2009. Ambiguity and Nonparticipation: The Role of Regulation. Review of Financial Studies 22, 1817-1843.

Easley, D., O'Hara, M., 2010. Microstructure and Ambiguity. Journal of Finance 65, 1817-1846.

Eichler, S., Karmann, A., & Maltritz, D., 2011. The term structure of banking crisis risk in the United States: A market data based compound option approach. Journal of Banking & Finance 35, 876-885.

Einhorn, H.J., Hogarth, R.M., 1985. Ambiguity and uncertainty in probabilistic inference. Psychological Review 92, 433-461.

Einhorn, H.J., Hogarth, R.M., 1986. Judging probable cause. Psychological Bulletin 99, 3-19.

Fisher, K.L., Statman, M., 2000. Investment Sentiment and stock returns. Financial Analysts Journal 56, 16-23.

Friberg, R., Seiler, T., 2017. Risk and ambiguity in 10-Ks: An examination of cash holdings and derivatives use. Journal of Corporate Finance 45, 608-631.

Friesen, G.C., Zhang, Y., & Zorn, T.S., 2012. Heterogeneous beliefs and risk-neutral skeweness. Journal of Financial and Quantitative Analysis 47, 851-872.

Gande, A., Kalpathy, S., 2017. CEO compensation and risk-taking at financial firms: Evidence from U.S. federal loan assistance. Journal of Corporate Finance 47, 131-150.

Ghirardato, P., Maccheroni, F., & Marinacci, M., 2004. Differentiating ambiguity and ambiguity attitude. Journal of Economic Theory 118, 133-173.

Hey, J.D., Lotito, G., & Maffioletti, A., 2010. The descriptive and predictive adequacy of theories of decision-making under uncertainty/ambiguity. Journal of Risk and Uncertainty 41, 81-111.

Hogarth, R.M., Kunreuther, H., 1989. Risk, ambiguity and insurance. Journal of Risk and Uncertainty 2, 5–35.

Hogarth, R.M., Einhorn, H.J., 1990. Venture theory: A model of decision weights. Management Science 36, 780-803.

Huang, D., Jiang, F., Tu, J., & Zhou, G., 2014. Investor Sentiment Aligned: A Powerful Predictor of Stock Returns. Review of Financial Studies 28, 791-837.

Ivanov, I.T., Santos, J.A.C., & Vo, T., 2016. The transformation of banking: Tying loan interest rates to borrowers' CDS spreads. Journal of Corporate Finance 38, 150-165.

Izhakian, Y., Yermack, D., 2017. Risk, ambiguity, and the exercise of employee stock options. Journal of Financial Economics 124, 65-85.

Jacquart, P., Antonakis, J., 2015. When Does Charistma Matter for Top-Level Leaders? Effect of Attributional Ambiguity. Academy of Management Journal 58, 1051-1074.

Jin, J.Y., Kanagaretnam, K., Liu, Y., & Lobo, G., 2019. Economic policy uncertainty, monetary policy uncertainty, and bank earnings opacity. Journal of Accounting and Public Policy 38, 199-218.

Jurado, K., Ludvigson, S.C., & Ng, S., 2015. Measuring uncertainty. American Economic Review 105, 1177-1216.

Kast, R., Lapied, A., 2010. Valuing future cash flows with non separable discount factors and non additive subjective measures: conditional Choquet capacities on time and on uncertainty. Theory and Decision 69, 27-53.

Kast, R., Lapied, A., & Roubaud, D., 2014. Modelling under ambiguity with dynamically consistent Choquet random walks and Choquet-Brownian motions. Economic Modelling 38, 495-503.

Kelly, B., Lustig, H., & Van, Nieuwerburgh, S., 2016. Too-systemic-to-fail: What option markets imply about sector-wide government guarantees. American Economic Review 106, 1278-1319.

Keynes, J.M., 1921. A Treatise on Probability. London: Macmillan.

King, A.W., Zeithaml, C.P., 2001. Competencies and firm performance: Examining the causal ambiguity paradox. Strategic Management Journal 22, 75-99.

Knight, F.H., 1921. Risk, Uncertainty and Profit. Boston, MA: Houghton Mifflin.

Kuhnen, C.M., Melzer, B.T., 2018. Noncognitive abilities and financial delinquency: The role of self-efficacy in avoiding financial distress. Journal of Finance 73, 2837-2869.

Leiblein, M.J., Chen, J.S., & Posen, H.E., 2017. Resource allocation in strategic market factors: A realistic real options approach. Journal of Management 43, 2588-2608.

Low, C., 2004. The fear and exuberance from implied volatility of S&P 100 index options. Journal of Business 77, 527-546.

Maenhout, P.J., 2004. Robust Portfolio Rules and Asset Pricing. Review of Financial Studies 17, 951-983.

March, J.G., 1978. Bounded rationality, ambiguity and the engineering of choice. Bell Journal of Economics 9, 587-608.

Merton, R.C., 1973. Theory of rational option pricing. Bell Journal of Economics and Management Science 4, 141-183.

Mosakowski, E., 1997. Strategy making under causal ambiguity: Conceptual issues and empirical evidence. Organization Science 8, 414-442.

Newey, W.K., West, K.D., 1987. A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica 55, 703-708.

Osambela, E., 2015. Differences of Opinion, Endogenous Liquidity, and Asset Prices. Review of Financial Studies 28, 1914-1959.

Park, H.D., Patel, P.C., 2015. How does ambiguity influence IPO underpricing? The role of the signalling environment. Journal of Management Studies 52, 796-818.

Pesaran, M.H., 2004. General diagnostic tests for cross section dependence in panels. Cambridge Working Papers in Economics No. 0435.

Petkova, A.P., Wadhwa, A., Yao, X., & Jain, S., 2014. Reputation and Decision Making under Ambiguity: A Study of U.S. Venture Capital Firms' Investments in the Emerging Clean Energy Sector. Academy of Management Journal 57, 422-448.

Poon, M., 2009. From new deal institutions to capital markets: Commercial consumer risk scores and the making of subprime mortgage finance. Accounting, Organizations and Society 34, 654-674.

Poon, S-H., Granger, C., 2003. Forecasting volatility in financial markets: A review. Journal of Economic Literature 41, 478-539.

Poteshman, A.M., 2006. Unusual option market activity and the terrorist attacks of September 11, 2001. Journal of Business 79, 1703–1726.

Poteshman, A.M., Serbin, V., 2003. Clearly irrational financial market behaviour: Evidence from the early exercise of exchange traded stock options. Journal of Finance 58, 37-70.

Powell, T.C., Lovallo, D., & Caringal, C., 2006. Causal ambiguity, management perception, and firm performance. Academy of Management Review 31, 175-196.

Quiggin, J., 1982. A theory of anticipated utility. Journal of Economic Behavior & Organization 3, 323–343.

Samuelson, P., 2008. Asymmetric or symmetric time preference and discounting in many facets of economic theory: A miscellany. Journal of Risk and Uncertainty 37, 107-114.

Schmeidler, D., 1989. Subjective probability and expected utility without additivity. Econometrica 57, 571–587.

Shu, H-C., 2010. Investor mood and financial markets. Journal of Economic Behavior & Organization 76(2), 267-282.

Sommer, S.J., Loch, C.H., & Dong, J., 2009. Managing Complexity and Unforeseeable Uncertainty in Startup Companies. Organization Science 20, 118-133.

Stiglitz, J.E., 2011. Rethinking macroeconomics: what failed, and how to repair it. Journal of the European Economic Association 9(4), 591-645.

Sun, Y., Phillips, P.C.B, & Jin, S., 2008. Optimal Bandwidth Selection in Heteroskedasticity–Autocorrelation Robust Testing. Econometrica 76, 175-194.

Swidler, S., Wilcox, J.A., 2002. Information about Bank Risk in Options Prices. Journal of Banking & Finance 26, 1033-1057.

Tarashev, N.A., 2007. Speculative attacks and the information role of the interest rate. Journal of the European Economic Association 5, 1-36.

Uppal, R., Wang, T., 2003. Model Misspecification and Underdiversification. Journal of Finance 58, 2465-2486.

Vaaler, P.M., McNamara, G., 2004. Crisis and competition in expert organizational decision making: Credit-rating agencies and their response to turbulence in emerging economies. Organization Science 15, 687–703.

Vallascas, F., Mollah, S., & Keasey, K., 2017. Does the impact of board independence on large bank risks change after the global financial crisis?. Journal of Corporate Finance 44, 149-166.

Vinogradov, D., 2012. Destructive effects of constructive ambiguity in risky times. Journal of International Money and Finance 31, 1459-1481.

Wegener, C., Kruse, R., & Basse, T., 2019. The walking debt crisis. Journal of Economic Behavior & Organization 157, 382-402.

Yan, H., 2008. Natural selection in financial markets: Does it work?. Management Science 54, 1935-1950.

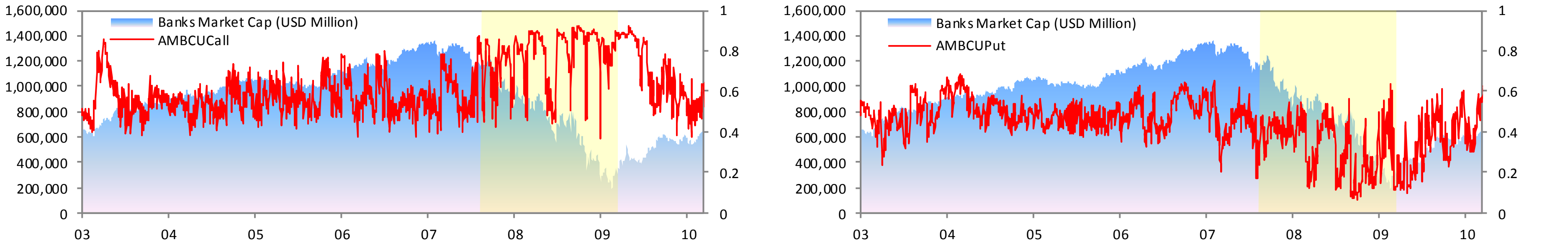

Figure 1a – U.S. systemic banks market capitalization and investor ambiguity (AMB^{CU}) under CU for calls and puts

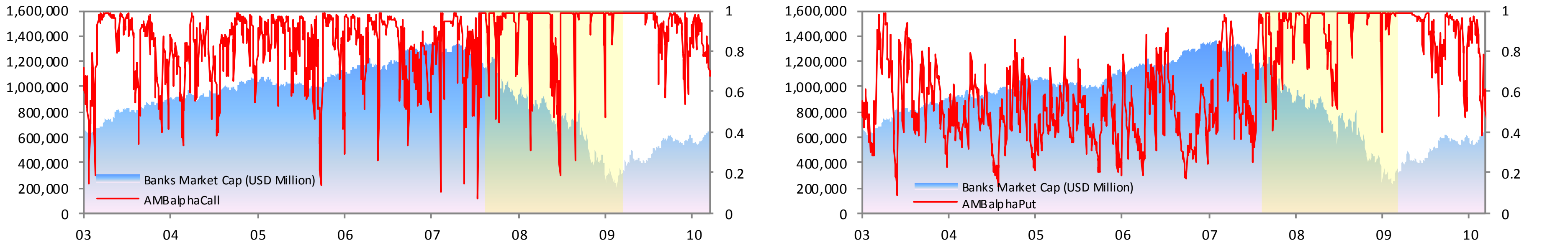

Figure 1b – U.S. systemic banks market capitalization and investor ambiguity (AMB$^{alpha\text{-}MEP}$) under α-MEP for calls and puts

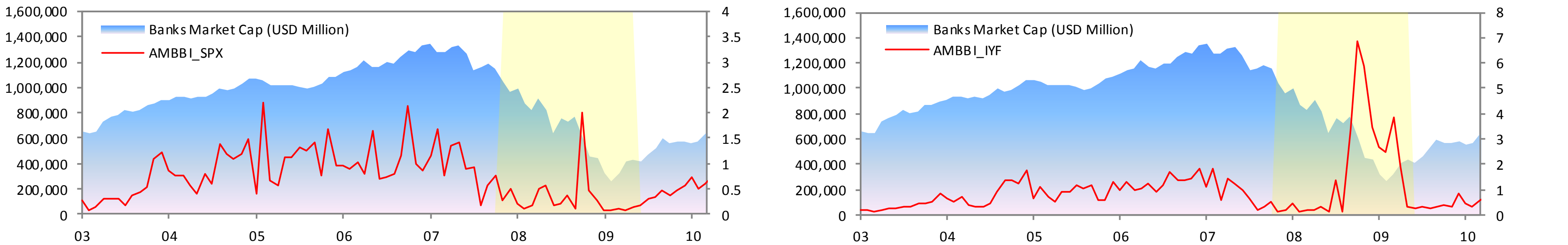

Figure 1c – U.S. systemic banks market capitalization and investor ambiguity (AMB^{BI}) under EUUP for SPX and IYF

Table 1 - Descriptive statistics and correlation matrix

The table reports summary statistics and correlations for the independent variables used in Eqs. (19-21). We present results for call and put options on US banks' equities and for the iShares U.S. Financials ETF over 2003-2009. *AMB*s are obtained using Eqs. (2-6 and 12-18) under CU, α-MEP and EUUP. IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

Variable	Mean	SD	Correlation																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. $IV_{Call.OTM}$	0.31	0.26	1.00																		
2. $IV_{Call.ITM}$	0.34	0.27	0.99	1.00																	
3. $IV_{Put.OTM}$	0.37	0.28	0.99	0.98	1.00																
4. $IV_{Put.ITM}$	0.35	0.26	0.99	0.98	0.99	1.00															
5. $AMB^{CU}_{Call.OTM}$	***0.62***	0.16	0.55	0.57	0.58	0.55	1.00														
6. $AMB^{CU}_{Call.ITM}$	***0.63***	0.14	0.54	0.55	0.56	0.55	***0.80***	1.00													
7. $AMB^{CU}_{Put.OTM}$	***0.46***	0.12	-0.54	-0.54	-0.54	-0.54	***-0.58***	***-0.60***	1.00												
8. $AMB^{CU}_{Put.ITM}$	***0.42***	0.14	-0.49	-0.51	-0.52	-0.50	***-0.70***	***-0.65***	***0.70***	1.00											
9. $AMB^{alpha}_{Call.OTM}$	***0.85***	0.19	0.21	0.23	0.25	0.23	0.49	0.46	-0.34	-0.43	1.00										
10. $AMB^{alpha}_{Call.ITM}$	***0.85***	0.16	0.21	0.21	0.25	0.24	0.54	0.55	-0.39	-0.47	***0.85***	1.00									
11. $AMB^{alpha}_{Put.OTM}$	***0.50***	0.33	0.63	0.63	0.63	0.63	0.71	0.72	-0.63	-0.69	***0.54***	***0.58***	1.00								
12. $AMB^{alpha}_{Put.ITM}$	***0.77***	0.18	0.51	0.54	0.53	0.50	0.65	0.59	-0.49	-0.68	***0.63***	***0.54***	***0.82***	1.00							
13. AMB^{BI}_{IYF}	***1.06***	1.18	0.55	0.55	0.55	0.56	0.31	0.34	-0.46	-0.31	0.14	0.20	0.28	0.19	1.00						
14. SKEW	117.72	5.37	-0.29	-0.28	-0.30	-0.27	-0.21	-0.12	0.12	0.16	-0.04	0.03	-0.24	-0.23	0.11	1.00					
15. $OI_{Call.OTM}$	495511	751162	0.54	0.55	0.59	0.57	0.41	0.43	-0.32	-0.38	0.17	0.19	0.45	0.38	0.21	-0.18	1.00				
16. $OI_{Call.ITM}$	190402	239505	0.12	0.13	0.14	0.12	0.13	0.16	-0.05	-0.15	0.06	0.07	0.07	0.12	0.07	0.01	0.46	1.00			
17. $OI_{Put.OTM}$	450033	497384	0.33	0.33	0.36	0.34	0.33	0.35	-0.20	-0.30	0.16	0.17	0.36	0.34	0.13	-0.14	0.69	0.79	1.00		
18. $OI_{Put.ITM}$	190402	239505	0.57	0.57	0.61	0.60	0.41	0.42	-0.34	-0.38	0.17	0.18	0.48	0.39	0.20	-0.21	0.97	0.36	0.59	1.00	
19. SDVIX	0.90	0.39	0.33	0.35	0.34	0.35	0.34	0.30	-0.40	-0.37	0.23	0.21	0.43	0.33	0.36	0.12	0.23	-0.14	0.10	0.26	1.00

Table 2 - The effect of ambiguity on systemic banking risk

The table summarizes our 2003-2009 daily regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. DR stands for systemic banks' downside risk, EBETA is systemic banks' market beta risk, and CR is systemic banks' credit risk. AMB^{CU}_{SUMDEV} and AMB^{alpha}_{SUM} capture the overall degree of ambiguity in the systemic banking options market under CU and α-MEP (Eqs. (14) and (18)). AMB^{BI}_{SPX} proxies for the overall degree of ambiguity characterizing the SPX index. IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

	Overall Period																						
	Downside Risk (DR)								Systematic Risk (EBETA)						Credit Risk (CR)								
	1.OTM	2.ITM	3.OTM	4.ITM	5.OTM	6.ITM	7.OTM	8.ITM	9.OTM	10.ITM	11.OTM	12.ITM	13.OTM	14.ITM	15.OTM	16.ITM	17.OTM	18.ITM	19.OTM	20.OTM	21.ITM	22.OTM	23.ITM
Cst.	0.317	0.437	0.193	0.345	0.153	0.214	0.582**	0.582**	2.168***	2.323***	1.855***	2.115***	1.609***	1.682***	0.161	0.254	0.071	0.185	0.130	-0.243	0.147	0.585*	0.585*
	(1.144)	(1.509)	(0.743)	(1.278)	(0.599)	(0.804)	(2.037)	(2.037)	(5.734)	(6.197)	(5.677)	(6.482)	(5.087)	(5.378)	(0.547)	(0.882)	(0.250)	(0.675)	(0.458)	(-0.634)	(0.516)	(1.892)	(1.892)
IV	1.294***	1.351***	1.168***	1.231***	1.235***	1.307***	1.344***	1.344***	1.293***	1.313***	0.972***	1.042***	1.090***	1.188***	0.414***	0.413***	0.321**	0.323**	0.402***	0.476***	0.392***	0.493***	0.493***
	(12.505)	(12.067)	(11.851)	(11.782)	(12.407)	(12.094)	(13.368)	(13.368)	(12.841)	(12.655)	(11.588)	(12.720)	(10.990)	(11.852)	(3.455)	(3.495)	(2.428)	(2.553)	(3.199)	(3.135)	(3.274)	(3.977)	(3.977)
AMB^{CU}_{SUMDEV}	-	-	***0.663****	***0.644****	-	-	-	-	-	-	***1.680****	***1.466****	-	-	-	-	***0.486***	***0.486***	-	-	-	-	-
	-	-	***(2.914)***	***(3.163)***	-	-	-	-	-	-	***(5.068)***	***(4.692)***	-	-	-	-	***(2.014)***	***(2.336)***	-	-	-	-	-
AMB^{alpha}_{SUM}	-	-	-	-	***0.191****	***0.268****	-	-	-	-	-	-	***0.650****	***0.770****	-	-	-	-	***0.018***	***0.155****	***0.128***	-	-
	-	-	-	-	***(3.541)***	***(3.668)***	-	-	-	-	-	-	***(7.324)***	***(6.573)***	-	-	-	-	***(0.804)***	***(2.927)***	***(2.368)***	-	-
AMB^{BI}_{SPX}	-	-	-	-	-	-	***0.060****	***0.060****	-	-	-	-	-	-	-	-	-	-	-	-	-	***0.095****	***0.095****
	-	-	-	-	-	-	***(3.798)***	***(3.798)***	-	-	-	-	-	-	-	-	-	-	-	-	-	***(2.733)***	***(2.733)***
SKEW	-0.004	-0.005**	-0.003	-0.004*	-0.003	-0.004*	-0.007***	-0.007***	-0.012***	-0.013***	-0.009***	-0.011***	-0.009***	-0.012***	-0.003	-0.004*	-0.002	-0.003*	-0.003	0.001	-0.004*	-0.008***	-0.008***
	(-1.642)	(-2.017)	(-1.227)	(-1.848)	(-1.392)	(-1.917)	(-2.721)	(-2.721)	(-3.706)	(-4.151)	(-3.306)	(-4.266)	(-3.344)	(-4.232)	(-1.478)	(-1.892)	(-1.145)	(-1.750)	(-1.447)	(0.284)	(-1.827)	(-2.930)	(-2.930)
OI	-0.000	-0.000***	-0.000*	-0.000***	-0.000*	-0.000***	-0.000	-0.000	0.000**	0.000**	0.000*	0.000*	0.000*	0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(-1.543)	(-2.843)	(-1.831)	(-3.203)	(-1.926)	(-3.096)	(-1.479)	(-1.479)	(2.175)	(2.469)	(1.950)	(1.905)	(1.718)	(2.084)	(1.195)	(1.050)	(1.056)	(0.820)	(1.133)	(1.030)	(0.961)	(1.308)	(1.308)
SDVIX	0.099**	0.084**	0.055	0.054	0.069	0.064	0.098***	0.098***	-0.026	-0.029	-0.136**	-0.098	-0.128**	-0.086	0.218***	0.223***	0.187***	0.200***	0.213***	-	0.213***	0.218***	0.218***
	(2.377)	(1.961)	(1.369)	(1.358)	(1.573)	(1.476)	(2.640)	(2.640)	(-0.424)	(-0.512)	(-2.083)	(-1.551)	(-2.128)	(-1.492)	(2.874)	(2.920)	(2.625)	(2.772)	(2.740)	-	(2.788)	(3.195)	(3.195)
Adj R^2	75.99%	76.25%	**77.45%**	**77.90%**	**76.71%**	**76.97%**	**76.59%**	**76.59%**	65.30%	65.97%	**71.12%**	**71.29%**	**70.57%**	**69.74%**	44.12%	42.83%	**45.79%**	**44.84%**	**44.15%**	**37.19%**	**43.15%**	**47.43%**	**47.43%**
F	1260.129	1278.035	1093.642	1122.511	1049.293	1064.760	1041.937	1041.937	749.600	772.203	784.412	791.083	763.891	734.367	315.076	298.955	269.745	259.630	252.504	236.473	242.563	288.070	288.070

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 3 Panel A - The effect of ambiguity on downside risk under CU

The table summarizes our daily DR regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. We contrast 2003-2006 results (**Stable Period**) vs. results from 2007-2009 (**Uncertain Period**) for calls and puts. 2003-2009 results (**Overall Period**) are also reported for comparison. AMB^{CU} is the elicited ambiguity indicator under CU based on Eqs. (12-13). IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

		Overall Period				Stable Period				Uncertain Period			
		Downside Risk (DR)				Downside Risk (DR)				Downside Risk (DR)			
		1.OTM	**2.ITM**	**3.OTM**	**4.ITM**	**5.OTM**	**6.ITM**	**7.OTM**	**8.ITM**	**9.OTM**	**10.ITM**	**11.OTM**	**12.ITM**
Calls	Cst.	0.397	0.440	0.104	0.222	0.346***	0.381***	0.335***	0.393***	1.737**	1.961***	1.217*	1.464**
		(1.371)	(1.432)	(0.410)	(0.796)	(3.444)	(4.208)	(3.310)	(4.264)	(2.368)	(2.639)	(1.752)	(2.014)
	IV	0.868***	0.818***	0.813***	0.749***	0.543***	0.505***	0.544***	0.501***	0.812***	0.764***	0.762***	0.710***
		(11.599)	(13.494)	(11.564)	(13.023)	(4.607)	(4.771)	(4.626)	(4.800)	(12.138)	(12.863)	(11.311)	(11.638)
	AMB^{CU}	-	-	***0.145****	***0.145****	-	-	0.030	-0.053	-	-	***0.148****	***0.159****
		-	-	***(3.736)***	***(3.468)***	-	-	(0.700)	(-1.264)	-	-	***(3.041)***	***(2.814)***
	SKEW	-0.059*	-0.061*	-0.045	-0.059*	-0.241***	-0.266***	-0.238***	-0.262***	-0.140**	-0.154**	-0.118**	-0.138**
		(-1.833)	(-1.754)	(-1.528)	(-1.778)	(-2.715)	(-3.297)	(-2.681)	(-3.278)	(-2.387)	(-2.564)	(-2.090)	(-2.342)
	OI	-0.111**	-0.057*	-0.132***	-0.075**	-0.059	-0.095*	-0.056	-0.093*	-0.202***	-0.160***	-0.223***	-0.196***
		(-2.440)	(-1.750)	(-2.821)	(-2.130)	(-1.042)	(-1.908)	(-0.986)	(-1.835)	(-3.677)	(-3.534)	(-3.944)	(-4.116)
	SDVIX	0.111***	0.077*	0.083**	0.056	-0.066	-0.072	-0.070	-0.070	0.067	0.010	0.053	0.001
		(2.821)	(1.715)	(2.169)	(1.303)	(-1.219)	(-1.271)	(-1.267)	(-1.242)	(1.188)	(0.162)	(0.997)	(0.021)
	Adj R^2	76.01%	74.07%	**77.34%**	**75.48%**	49.58%	47.97%	49.61%	48.19%	64.51%	61.76%	**66.13%**	**63.64%**
	F	1260.889	1137.068	1087.157	980.291	248.267	232.888	199.114	188.160	266.367	236.823	229.039	205.472
Puts	Cst.	0.262	0.492*	0.533*	0.600**	0.064	0.130**	0.065	0.139**	1.497**	2.127***	1.501**	2.164***
		(0.966)	(1.694)	(1.866)	(2.026)	(0.988)	(2.050)	(1.013)	(2.231)	(2.381)	(2.821)	(2.402)	(2.895)
	IV	0.806***	0.898***	0.742***	0.858***	0.753***	0.684***	0.753***	0.687***	0.741***	0.819***	0.681***	0.787***
		(13.144)	(11.636)	(14.018)	(12.018)	(14.136)	(11.773)	(14.204)	(11.542)	(12.532)	(12.589)	(12.803)	(12.545)
	AMB^{CU}	-	-	***-0.142****	***-0.120****	-	-	-0.003	-0.073	-	-	***-0.155***	***-0.120***
		-	-	***(-2.794)***	***(-2.959)***	-	-	(-0.079)	(-1.580)	-	-	***(-2.326)***	***(-2.231)***
	SKEW	-0.046	-0.075**	-0.045	-0.066**	-0.032	-0.109*	-0.033	-0.103*	-0.123**	-0.177***	-0.098*	-0.165***
		(-1.516)	(-2.352)	(-1.518)	(-2.170)	(-0.547)	(-1.902)	(-0.560)	(-1.776)	(-2.421)	(-2.948)	(-1.944)	(-2.783)
	OI	0.033	-0.149***	0.032	-0.161***	-0.062	-0.124***	-0.062	-0.126***	-0.026	-0.241***	-0.008	-0.248***
		(0.673)	(-3.189)	(0.665)	(-3.318)	(-1.421)	(-2.967)	(-1.423)	(-3.033)	(-0.370)	(-5.122)	(-0.118)	(-5.011)
	SDVIX	0.091**	0.098**	0.056	0.070*	-0.132***	-0.071	-0.132***	-0.078	0.058	0.064	0.017	0.039
		(2.098)	(2.370)	(1.333)	(1.720)	(-2.625)	(-1.404)	(-2.608)	(-1.491)	(0.897)	(1.074)	(0.266)	(0.683)
	Adj R^2	75.27%	76.69%	**76.57%**	**77.67%**	64.08%	58.24%	64.04%	58.73%	60.17%	64.43%	**61.93%**	**65.59%**
	F	1211.649	1309.242	1040.616	1107.734	449.612	351.804	359.347	287.316	221.595	265.475	190.997	223.640

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 3 Panel B - The effects of ambiguity on downside risk under α-MEP and EUUP

The table summarizes our daily DR regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. We contrast 2003-2006 results (**Stable Period**) vs. results from 2007-2009 (**Uncertain Period**) for calls and puts. 2003-2009 results (**Overall Period**) are also reported for comparison. $AMB^{alpha\text{-}MEP}$ and AMB^{BI}_{IYF} are the ambiguity indicators under α-MEP and EUUP based on Eqs. (16-17) and Eq. (6). IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

		Overall Period				Stable Period				Uncertain Period			
		Downside Risk (DR)				Downside Risk (DR)				Downside Risk (DR)			
		1.OTM	2.ITM	3.OTM	4.ITM	5.OTM	6.ITM	7.OTM	8.ITM	9.OTM	10.ITM	11.OTM	12.ITM
Calls	Cst.	0.280	0.310	0.871***	0.970***	0.306***	0.342***	0.288***	0.316***	1.588**	1.810**	2.644***	2.872***
		(1.024)	(1.070)	(3.072)	(3.325)	(3.148)	(3.624)	(4.116)	(4.696)	(2.286)	(2.543)	(3.771)	(4.089)
	IV	1.362***	1.206***	1.166***	1.029***	0.484***	0.398***	0.369***	0.294***	1.230***	1.111***	0.876***	0.769***
		(11.659)	(13.473)	(10.202)	(11.629)	(5.198)	(5.277)	(4.384)	(4.442)	(12.007)	(12.432)	(8.243)	(8.193)
	AMB^{alpha}	0.140***	0.236***	-	-	0.025**	0.028	-	-	0.208**	0.304**	-	-
		(3.661)	(4.016)	-	-	(2.296)	(1.471)	-	-	(2.229)	(2.536)	-	-
	AMB^{BI}_{IYF}	-	-	0.069***	0.079***	-	-	-0.032***	-0.033***	-	-	0.102***	0.111***
		-	-	(4.002)	(4.527)	-	-	(-5.211)	(-5.847)	-	-	(5.165)	(5.563)
	SKEW	-0.004*	-0.005*	-0.008***	-0.009***	-0.002***	-0.002***	-0.001**	-0.001***	-0.014**	-0.016***	-0.021***	-0.022***
		(-1.833)	(-1.939)	(-3.473)	(-3.574)	(-2.653)	(-3.231)	(-2.334)	(-2.675)	(-2.445)	(-2.707)	(-3.564)	(-3.771)
	OI	0.000**	0.000*	0.000**	0.000**	0.000	0.000**	0.000	0.000	0.000***	0.000***	0.000***	0.000***
		(-2.517)	(-1.936)	(-2.308)	(-2.381)	(-0.771)	(-2.016)	(-0.425)	(-0.630)	(-3.757)	(-3.828)	(-3.952)	(-3.376)
	SDVIX	0.102**	0.065	0.084***	0.049	-0.014	-0.014	-0.016*	-0.016*	0.072	0.004	-0.041	-0.101*
		(2.483)	(1.400)	(2.892)	(1.452)	(-1.469)	(-1.385)	(-1.748)	(-1.662)	(1.108)	(0.052)	(-0.845)	(-1.919)
	Adj R^2	**76.39%**	**74.84%**	**78.41%**	**77.27%**	**50.50%**	48.56%	**56.40%**	**55.21%**	**64.80%**	**62.49%**	**71.24%**	**69.95%**
	F	1030.354	947.393	1156.379	1083.009	206.230	190.924	261.285	248.972	215.976	195.580	290.365	272.860
Puts	Cst.	0.131	0.200	0.788***	0.922***	0.060	0.077	0.072	0.129**	1.316**	1.402**	2.332***	2.902***
		(0.516)	(0.789)	(2.866)	(3.249)	(0.917)	(1.150)	(1.100)	(2.048)	(2.132)	(2.013)	(3.693)	(4.188)
	IV	1.087***	1.345***	0.971***	1.192***	0.685***	0.778***	0.611***	0.648***	0.992***	1.182***	0.659***	0.882***
		(12.815)	(11.815)	(10.725)	(10.205)	(14.227)	(11.282)	(10.328)	(8.441)	(11.841)	(12.106)	(6.300)	(8.390)
	AMB^{alpha}	0.143***	0.246***	-	-	0.004	0.039***	-	-	0.156*	0.496***	-	-
		(3.370)	(4.246)	-	-	(0.432)	(2.646)	-	-	(1.752)	(3.696)	-	-
	AMB^{BI}_{IYF}	-	-	0.074***	0.065***	-	-	-0.016***	-0.023***	-	-	0.115***	0.101***
		-	-	(4.116)	(3.646)	-	-	(-3.250)	(-4.618)	-	-	(5.426)	(5.032)
	SKEW	-0.002	-0.004**	-0.008***	-0.009***	0.000	-0.001	0.000	-0.001	-0.012**	-0.015***	-0.018***	-0.023***
		(-1.127)	(-2.006)	(-3.319)	(-3.832)	(-0.499)	(-1.460)	(-0.195)	(-1.154)	(-2.257)	(-2.597)	(-3.480)	(-4.059)
	OI	0.000	0.000***	0.000	0.000**	0.000	0.000***	0.000	0.000***	0.000	0.000***	0.000	0.000***
		(0.331)	(-3.488)	(0.991)	(-2.505)	(-1.477)	(-3.096)	(-0.856)	(-2.751)	(-0.598)	(-5.346)	(0.609)	(-4.219)
	SDVIX	0.061	0.078*	0.066**	0.074**	-0.024***	-0.016*	-0.024***	-0.016*	0.050	0.054	-0.061	-0.041
		(1.271)	(1.800)	(2.157)	(2.413)	(-2.641)	(-1.779)	(-2.725)	(-1.781)	(0.666)	(0.817)	(-1.151)	(-0.827)
	Adj R^2	**75.96%**	**77.49%**	**78.05%**	**78.76%**	64.07%	**59.86%**	**65.46%**	**61.29%**	**60.52%**	**65.76%**	**68.54%**	**70.90%**
	F	1006.561	1096.576	1132.434	1181.126	359.796	301.090	382.342	319.597	180.047	225.348	255.513	285.549

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 4 - The effect of ambiguity on systematic risk under CU and α -MEP

The table summarizes our daily EBETA regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. We contrast 2003-2006 results (**Stable Period**) vs. results from 2007-2009 (**Uncertain Period**) for calls and puts. 2003-2009 results (**Overall Period**) are also reported for comparison. AMB^{CU} and $AMB^{alpha\text{-}MEP}$ are the ambiguity indicators under CU and α-MEP based on Eqs. (12-13) and Eqs. (16-17). IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

		Overall Period						Stable Period						Uncertain Period					
		Systematic Risk (EBETA)						Systematic Risk (EBETA)						Systematic Risk (EBETA)					
		1.OTM	2.ITM	3.OTM	4.ITM	5.OTM	6.ITM	7.OTM	8.ITM	9.OTM	10.ITM	11.OTM	12.ITM	13.OTM	14.ITM	15.OTM	16.ITM	17.OTM	18.ITM
Calls	Cst.	2.255***	2.490***	1.547***	1.960***	1.876***	2.173***	1.579***	1.643***	1.432***	1.583***	1.210***	1.246***	4.780***	4.759***	3.651***	3.960***	4.351***	4.554***
		(5.736)	(6.489)	(4.795)	(6.156)	(5.259)	(6.298)	(8.741)	(9.269)	(7.809)	(8.508)	(7.578)	(7.163)	(5.276)	(5.753)	(4.588)	(5.321)	(5.085)	(5.772)
	IV	0.677***	0.721***	0.572***	0.589***	1.324***	1.322***	0.258***	0.253***	0.265***	0.261***	0.734***	0.741***	0.560***	0.529***	0.468***	0.454***	0.973***	0.895***
		(11.646)	(13.647)	(11.514)	(13.118)	(11.430)	(13.240)	(4.685)	(4.406)	(5.132)	(4.494)	(7.172)	(7.484)	(10.797)	(11.383)	(9.691)	(10.043)	(10.395)	(10.851)
	AMB^{CU}	-	-	0.276***	0.278***	-	-	-	-	0.185***	0.111**	-	-	-	-	0.272***	0.217***	-	-
		-	-	(5.369)	(5.453)	-	-	-	-	(4.103)	(2.258)	-	-	-	-	(4.530)	(3.779)	-	-
	AMB^{alpha}	-	-	-	-	0.457***	0.574***	-	-	-	-	0.236***	0.291***	-	-	-	-	0.598***	0.412***
		-	-	-	-	(7.224)	(5.776)	-	-	-	-	(8.195)	(6.844)	-	-	-	-	(3.954)	(2.625)
	SKEW	-0.125***	-0.154***	-0.099***	-0.151***	-0.012***	-0.016***	-0.268***	-0.302***	-0.250***	-0.310***	-0.004***	-0.005***	-0.228***	-0.238***	-0.187***	-0.216***	-0.028***	-0.030***
		(-3.655)	(-4.611)	(-3.397)	(-5.127)	(-3.810)	(-5.188)	(-3.526)	(-4.021)	(-3.399)	(-4.155)	(-3.275)	(-3.843)	(-3.696)	(-4.261)	(-3.382)	(-4.140)	(-3.847)	(-4.416)
	OI	0.139	0.139***	0.100	0.106***	0.000	0.000***	-0.018	0.123***	0.002	0.119**	0.000	0.000***	0.067	0.250***	0.028	0.201***	0.000	0.000***
		(1.634)	(3.069)	(1.188)	(2.604)	(1.549)	(3.034)	(-0.362)	(2.752)	(0.045)	(2.519)	(1.255)	(3.159)	(0.769)	(5.592)	(0.323)	(4.019)	(0.592)	(4.733)
	SDVIX	-0.017	0.009	-0.071	-0.032	-0.062	-0.024	-0.047	-0.019	-0.071	-0.022	-0.043	-0.022	-0.239***	-0.193***	-0.264***	-0.206***	-0.343***	-0.276***
		(-0.350)	(0.214)	(-1.366)	(-0.684)	(-0.992)	(-0.417)	(-0.620)	(-0.255)	(-0.966)	(-0.301)	(-1.425)	(-0.751)	(-3.697)	(-3.423)	(-3.896)	(-3.338)	(-3.921)	(-3.548)
	Adj R^2	64.34%	65.26%	**69.22%**	**70.48%**	**66.93%**	**68.13%**	21.16%	22.85%	**24.41%**	**23.98%**	**37.22%**	**35.44%**	54.61%	61.18%	**60.20%**	**64.72%**	**56.60%**	**62.16%**
	F	718.618	748.319	716.499	760.722	644.895	681.303	68.505	75.471	65.974	64.477	120.300	111.436	176.680	231.127	177.638	215.258	153.310	192.879
Puts	Cst.	2.126***	2.329***	2.682***	2.631***	1.655***	1.478***	1.209***	1.478***	1.370***	1.554***	1.068***	1.097***	4.140***	5.047***	4.149***	5.156***	3.468***	3.423***
		(5.705)	(5.869)	(6.709)	(6.673)	(5.236)	(4.541)	(6.248)	(7.013)	(7.123)	(7.710)	(5.890)	(5.999)	(4.432)	(5.395)	(4.649)	(5.920)	(4.073)	(4.121)
	IV	0.689***	0.678***	0.586***	0.589***	0.989***	1.185***	0.409***	0.250***	0.399***	0.259***	0.851***	0.719***	0.534***	0.550***	0.427***	0.470***	0.713***	0.832***
		(10.899)	(11.586)	(10.451)	(13.059)	(8.618)	(10.948)	(5.862)	(4.540)	(5.521)	(4.687)	(6.252)	(4.780)	(8.844)	(10.407)	(6.875)	(9.401)	(6.641)	(8.566)
	AMB^{CU}	-	-	-0.229***	-0.264***	-	-	-	-	-0.139***	-0.248***	-	-	-	-	-0.276***	-0.292***	-	-
		-	-	(-4.258)	(-5.113)	-	-	-	-	(-2.634)	(-4.516)	-	-	-	-	(-4.514)	(-4.676)	-	-
	AMB^{alpha}	-	-	-	-	0.516***	0.716***	-	-	-	-	0.156***	0.280***	-	-	-	-	0.579***	1.110***
		-	-	-	-	(7.446)	(7.047)	-	-	-	-	(5.673)	(7.273)	-	-	-	-	(4.814)	(5.985)
	SKEW	-0.121***	-0.133***	-0.118***	-0.113***	-0.008***	-0.009***	-0.160**	-0.238***	-0.176**	-0.215***	-0.002	-0.003**	-0.188***	-0.249***	-0.145**	-0.218***	-0.019***	-0.023***
		(-3.788)	(-3.833)	(-4.027)	(-3.689)	(-2.974)	(-3.187)	(-2.069)	(-2.897)	(-2.393)	(-2.642)	(-1.592)	(-2.317)	(-3.009)	(-3.897)	(-2.471)	(-3.816)	(-2.750)	(-3.360)
	OI	0.176***	0.133	0.174***	0.107	0.000***	0.000	0.118***	-0.158**	0.114***	-0.168***	0.000**	0.000***	0.167**	0.051	0.199***	0.032	0.000	0.000
		(3.571)	(1.541)	(3.631)	(1.275)	(2.875)	(1.260)	(3.225)	(-2.462)	(3.035)	(-2.611)	(2.434)	(-3.005)	(2.214)	(0.530)	(2.702)	(0.355)	(1.540)	(0.255)
	SDVIX	-0.013	-0.031	-0.071	-0.094*	-0.139**	-0.109*	-0.061	-0.039	-0.069	-0.062	-0.040	-0.038	-0.238***	-0.241***	-0.311***	-0.300***	-0.388***	-0.374***
		(-0.290)	(-0.675)	(-1.494)	(-1.950)	(-2.324)	(-1.816)	(-0.808)	(-0.549)	(-0.968)	(-0.908)	(-1.469)	(-1.426)	(-3.767)	(-3.747)	(-4.713)	(-4.390)	(-4.815)	(-4.405)
	Adj R^2	65.62%	64.32%	**69.00%**	**69.16%**	**71.29%**	**68.62%**	27.76%	21.61%	**29.58%**	**27.66%**	**37.40%**	**37.63%**	55.30%	53.41%	**61.02%**	**60.59%**	**59.33%**	**58.34%**
	F	760.072	718.174	709.367	714.416	791.251	696.890	97.645	70.349	85.534	77.940	121.210	122.399	181.601	168.388	183.855	180.539	171.377	164.532

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 5 Panel A - The effect of ambiguity on credit risk under CU

The table summarizes our daily CR regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. We contrast 2003-2006 results (**Stable Period**) vs. results from 2007-2009 (**Uncertain Period**) for calls and puts. 2003-2009 results (**Overall Period**) are also reported for comparison. AMB^{CU} is the elicited Choquet ambiguity indicator based on Eqs. (12-13). IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

		Overall Period				**Stable Period**				**Uncertain Period**			
		Credit Risk (CR)				Credit Risk (CR)				Credit Risk (CR)			
		1.OTM	2.ITM	3.OTM	4.ITM	5.OTM	6.ITM	7.OTM	8.ITM	9.OTM	10.ITM	11.OTM	12.ITM
Calls	Cst.	0.228	0.312	0.068	0.150	0.262***	0.263**	0.173*	0.227**	0.117	0.566	-0.341	-0.010
		(0.783)	(1.054)	(0.235)	(0.520)	(2.586)	(2.564)	(1.886)	(2.235)	(0.150)	(0.767)	(-0.415)	(-0.013)
	IV	0.350***	0.430***	0.305**	0.355***	0.241**	0.256**	0.249**	0.265***	0.325***	0.373***	0.270**	0.295***
		(3.085)	(3.950)	(2.553)	(3.028)	(2.291)	(2.566)	(2.392)	(2.577)	(3.178)	(3.650)	(2.473)	(2.753)
	AMB^{CU}	-	-	***0.116****	***0.159******	-	-	***0.204******	***0.119*****	-	-	***0.161*****	***0.228******
		-	-	***(1.873)***	***(2.603)***	-	-	***(2.739)***	***(2.073)***	-	-	***(1.980)***	***(2.873)***
	SKEW	-0.071*	-0.087**	-0.060	-0.085**	-0.192***	-0.189**	-0.172**	-0.198***	-0.058	-0.103	-0.034	-0.081
		(-1.686)	(-1.989)	(-1.469)	(-2.049)	(-2.674)	(-2.519)	(-2.553)	(-2.603)	(-0.794)	(-1.486)	(-0.464)	(-1.187)
	OI	0.171	0.013	0.154	-0.006	0.062	0.015	0.084	0.011	0.182	0.007	0.159	-0.045
		(1.307)	(0.311)	(1.160)	(-0.148)	(1.120)	(0.316)	(1.531)	(0.233)	(1.588)	(0.107)	(1.379)	(-0.718)
	SDVIX	0.317***	0.325***	0.294***	0.301***	-0.056	-0.053	-0.082**	-0.056	0.434***	0.432***	0.419***	0.419***
		(2.847)	(2.994)	(2.679)	(2.889)	(-1.460)	(-1.406)	(-2.077)	(-1.492)	(3.587)	(3.543)	(3.572)	(3.701)
	Adj R^2	43.16%	40.85%	**43.99%**	**42.53%**	14.89%	15.08%	**18.84%**	**16.39%**	38.70%	35.36%	**40.58%**	**39.25%**
	F	303.008	275.745	250.960	236.457	44.998	45.653	47.714	40.441	93.182	80.852	80.761	76.448
Puts	Cst.	0.119	0.211	0.389	0.295	0.014	0.177**	0.128	0.214***	-0.112	0.146	-0.107	0.186
		(0.393)	(0.727)	(1.340)	(1.039)	(0.153)	(2.112)	(1.295)	(2.658)	(-0.137)	(0.189)	(-0.136)	(0.253)
	IV	0.464***	0.387***	0.370***	0.341***	0.425***	0.272***	0.412***	0.280***	0.420***	0.355***	0.334***	0.312***
		(3.882)	(3.275)	(3.091)	(2.820)	(3.589)	(2.692)	(3.467)	(2.732)	(3.860)	(3.439)	(3.176)	(2.971)
	AMB^{CU}	-	-	***-0.208******	***-0.137*****	-	-	***-0.179******	***-0.218******	-	-	***-0.222******	***-0.161*****
		-	-	***(-3.056)***	***(-2.289)***	-	-	***(-3.825)***	***(-3.968)***	-	-	***(-3.310)***	***(-2.174)***
	SKEW	-0.058	-0.069*	-0.055	-0.058	-0.043	-0.156***	-0.064	-0.135**	-0.040	-0.064	-0.005	-0.046
		(-1.318)	(-1.666)	(-1.380)	(-1.478)	(-0.728)	(-2.726)	(-1.046)	(-2.563)	(-0.522)	(-0.879)	(-0.067)	(-0.655)
	OI	0.062	0.132	0.060	0.119	0.029	0.103*	0.024	0.094	0.094	0.146	0.120	0.136
		(1.088)	(1.118)	(1.092)	(1.012)	(0.826)	(1.686)	(0.683)	(1.504)	(1.035)	(1.446)	(1.397)	(1.375)
	SDVIX	0.306***	0.302***	0.254***	0.269**	-0.090**	-0.068*	-0.101**	-0.088**	0.430***	0.429***	0.371***	0.396***
		(2.885)	(2.742)	(2.676)	(2.487)	(-2.204)	(-1.824)	(-2.532)	(-2.479)	(3.683)	(3.599)	(3.435)	(3.370)
	Adj R^2	44.81%	43.87%	**47.59%**	**45.15%**	21.34%	16.77%	**24.43%**	**21.41%**	40.78%	39.60%	**44.45%**	**41.68%**
	F	323.962	311.889	289.925	262.895	69.246	51.688	66.043	55.807	101.555	96.718	94.444	84.484

Newey-West t-statistics in parentheses; ***$p < 0.01$, **$p < 0.05$, * $p < 0.1$

Table 5 Panel B - The effect of ambiguity on credit risk under α-MEP and EUUP

The table summarizes our daily CR regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. We contrast 2003-2006 results (**Stable Period**) vs. results from 2007-2009 (**Uncertain Period**) for calls and puts. 2003-2009 results (**Overall Period**) are also reported for comparison. $AMB^{alpha\text{-}MEP}$ and AMB^{BI}_{IYF} are the ambiguity indicators under α -MEP and EUUP based on Eqs. (16-17) and Eq. (6). IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

		Overall Period				Stable Period				Uncertain Period			
		Credit Risk (CR)				Credit Risk (CR)				Credit Risk (CR)			
		1.OTM	2.ITM	3.OTM	4.ITM	5.OTM	6.ITM	7.OTM	8.ITM	9.OTM	10.ITM	11.OTM	12.ITM
Calls	Cst.	0.162	0.223	1.123***	1.136***	0.151*	0.119	0.181**	0.176**	-0.050	0.411	1.522***	1.790***
		(0.568)	(0.755)	(4.790)	(4.429)	(1.682)	(1.234)	(2.401)	(2.241)	(-0.065)	(0.559)	(2.662)	(3.062)
	IV	0.370***	0.425***	-0.015	0.131	0.328***	0.349***	0.133	0.137**	0.387***	0.423***	-0.169*	-0.043
		(3.033)	(3.864)	(-0.165)	(1.473)	(2.831)	(3.002)	(1.508)	(1.990)	(3.050)	(3.482)	(-1.950)	(-0.476)
	AMB^{alpha}	0.080**	0.162***	-	-	0.071***	0.105***	-	-	0.232**	0.313***	-	-
		(2.563)	(4.060)	-	-	(3.637)	(2.745)	-	-	(2.483)	(3.524)	-	-
	AMB^{BI}_{IYF}	-	-	0.131***	0.122***	-	-	-0.045***	-0.045***	-	-	0.158***	0.149***
		-	-	(5.060)	(4.522)	-	-	(-5.624)	(-4.967)	-	-	(6.190)	(5.334)
	SKEW	-0.004*	-0.005**	-0.011***	-0.011***	-0.002**	-0.002**	-0.001	-0.001	-0.005	-0.009*	-0.015***	-0.017***
		(-1.682)	(-2.153)	(-5.353)	(-5.020)	(-2.431)	(-2.294)	(-1.536)	(-1.370)	(-0.854)	(-1.667)	(-3.096)	(-3.547)
	OI	0.000	0.000	0.000***	0.000	0.000*	0.000	0.000**	0.000*	0.000	0.000	0.000***	0.000
		(1.289)	(0.150)	(2.755)	(0.163)	(1.878)	(0.405)	(2.079)	(1.680)	(1.516)	(-0.265)	(3.497)	(0.974)
	SDVIX	0.215***	0.218***	0.165***	0.180***	-0.020**	-0.017**	-0.019**	-0.016**	0.400***	0.397***	0.224***	0.253***
		(2.735)	(2.884)	(3.843)	(4.128)	(-2.206)	(-1.968)	(-2.229)	(-1.981)	(3.554)	(3.532)	(3.792)	(4.141)
	Adj R^2	**43.40%**	**41.62%**	**61.66%**	**57.60%**	**19.69%**	**20.50%**	**23.15%**	**23.27%**	**39.26%**	**36.53%**	**63.52%**	**57.97%**
	F	244.977	227.858	512.775	433.227	50.341	52.888	61.603	62.017	76.489	68.226	204.380	162.098
Puts	Cst.	-0.243	0.129	0.941***	1.066***	-0.004	0.114	0.031	0.175**	-0.970	-0.395	0.936	1.338**
		(-0.639)	(0.547)	(3.479)	(4.534)	(-0.047)	(1.487)	(0.357)	(2.091)	(-0.991)	(-0.486)	(1.346)	(2.267)
	IV	0.510***	0.395***	0.156	-0.002	0.487***	0.397***	0.326**	0.165	0.458***	0.386***	0.000	-0.133
		(3.424)	(3.786)	(1.620)	(-0.018)	(3.558)	(2.737)	(2.415)	(1.196)	(3.088)	(2.971)	(0.004)	(-1.440)
	AMB^{alpha}	0.106**	0.069	-	-	0.019	0.046	-	-	0.249**	0.370**	-	-
		(2.274)	(1.434)	-	-	(0.917)	(1.169)	-	-	(2.335)	(2.439)	-	-
	AMB^{BI}_{IYF}	-	-	0.116***	0.130***	-	-	-0.035***	-0.041***	-	-	0.145***	0.155***
		-	-	(4.371)	(5.005)	-	-	(-4.266)	(-5.188)	-	-	(5.437)	(5.916)
	SKEW	0.001	-0.003*	-0.010***	-0.010***	0.000	-0.001**	0.000	-0.001	0.007	-0.003	-0.011*	-0.013***
		(0.405)	(-1.824)	(-4.217)	(-5.088)	(-0.603)	(-2.513)	(-0.121)	(-1.610)	(0.848)	(-0.498)	(-1.874)	(-2.705)
	OI	0.000	0.000	0.000*	0.000***	0.000	0.000	0.000**	0.000**	0.000	0.000	0.000**	0.000***
		(0.613)	(1.298)	(1.833)	(2.721)	(0.737)	(1.629)	(2.080)	(1.973)	(0.593)	(1.317)	(2.416)	(3.391)
	SDVIX	-	0.205***	0.171***	0.157***	-0.022**	-0.019**	-0.021**	-0.021**	-	0.387***	0.242***	0.225***
		-	(3.286)	(3.939)	(3.678)	(-2.386)	(-2.156)	(-2.399)	(-2.430)	-	(3.552)	(4.112)	(3.877)
	Adj R^2	**37.95%**	**43.97%**	**59.48%**	**61.74%**	21.77%	18.15%	**25.46%**	**23.20%**	**25.05%**	**40.68%**	**60.96%**	**63.02%**
	F	244.253	250.754	468.163	514.534	56.991	45.614	69.720	61.787	49.786	81.098	183.401	200.082

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 6 - Monthly effect of ambiguity on systemic banking risk under CU

The table summarizes our 2003-2009 monthly regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. DR stands for systemic banks' downside risk, EBETA is systemic banks' market beta risk, and CR is systemic banks' credit risk. AMB^{CU} and AMB^{CU}_{SUMDEV} are the elicited ambiguity indicators under CU based on Eqs. (12-14). IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

		Overall Period																	
		Downside Risk (DR)						Systematic Risk (EBETA)						Credit Risk (CR)					
		1.OTM	2.ITM	3.OTM	4.ITM	5.OTM	6.ITM	7.OTM	8.ITM	9.OTM	10.ITM	11.OTM	12.ITM	13.OTM	14.ITM	15.OTM	16.ITM	17.OTM	18.ITM
Calls	Cst.	0.119	0.209	-0.115	0.053	-0.042	0.106	2.830***	2.806***	2.357***	2.490***	2.564***	2.661***	-0.195	0.076	-0.441	-0.090	-0.356	-0.025
		(0.197)	(0.338)	(-0.189)	(0.087)	(-0.073)	(0.179)	(3.676)	(3.627)	(3.153)	(3.388)	(3.703)	(3.648)	(-0.305)	(0.110)	(-0.684)	(-0.130)	(-0.584)	(-0.037)
	IV	1.212***	1.131***	1.141***	1.072***	1.050***	0.955***	1.089***	0.983***	0.946***	0.863***	0.820***	0.735***	0.366***	0.472***	0.291**	0.409***	0.203	0.298**
		(9.512)	(9.302)	(8.682)	(8.673)	(8.013)	(7.200)	(6.697)	(6.458)	(5.852)	(5.825)	(5.162)	(4.493)	(2.707)	(3.455)	(2.090)	(2.937)	(1.451)	(1.977)
	AMB^{CU}	-	-	0.311*	0.380*	-	-	-	-	0.628***	0.772***	-	-	-	-	0.327*	0.406*	-	-
		-	-	(1.794)	(1.860)	-	-	-	-	(2.946)	(3.151)	-	-	-	-	(1.776)	(1.764)	-	-
	AMB^{CU}_{SUMDEV}	-	-	-	-	0.479***	0.435***	-	-	-	-	0.793***	0.613***	-	-	-	-	0.479***	0.429**
		-	-	-	-	(3.108)	(2.755)	-	-	-	-	(4.242)	(3.148)	-	-	-	-	(2.911)	(2.385)
	SKEW	-0.001	-0.002	-0.001	-0.003	-0.000	-0.002	-0.016**	-0.016**	-0.015**	-0.017***	-0.014**	-0.015**	0.000	-0.003	0.001	-0.003	0.002	-0.002
		(-0.289)	(-0.436)	(-0.157)	(-0.508)	(-0.007)	(-0.306)	(-2.479)	(-2.448)	(-2.382)	(-2.709)	(-2.348)	(-2.426)	(0.030)	(-0.438)	(0.165)	(-0.506)	(0.311)	(-0.322)
	OI	0.000	0.000	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000***	0.000	0.000***	0.000	0.000***	0.000
		(0.264)	(0.474)	(0.141)	(0.167)	(0.697)	(0.149)	(-0.856)	(0.685)	(-1.108)	(0.194)	(-0.374)	(0.330)	(3.986)	(1.247)	(3.913)	(0.956)	(4.551)	(0.982)
	SDVIX	-0.000	-0.012	-0.016	-0.020	-0.070	-0.041	-0.107	-0.130	-0.139	-0.147*	-0.222***	-0.171**	0.168**	0.218***	0.152**	0.209***	0.099	0.189**
		(-0.007)	(-0.165)	(-0.233)	(-0.282)	(-0.998)	(-0.586)	(-1.185)	(-1.440)	(-1.610)	(-1.722)	(-2.607)	(-1.987)	(2.253)	(2.688)	(2.046)	(2.615)	(1.319)	(2.388)
	CRISISDUMMY	0.193***	0.198***	0.169**	0.155**	0.137**	0.141**	0.413***	0.409***	0.364***	0.321***	0.320***	0.328***	-0.019	0.000	-0.045	-0.046	-0.076	-0.056
		(2.969)	(2.956)	(2.573)	(2.221)	(2.138)	(2.098)	(4.981)	(4.865)	(4.516)	(3.832)	(4.128)	(3.953)	(-0.279)	(0.005)	(-0.649)	(-0.580)	(-1.107)	(-0.727)
	Adj R^2	76.92%	75.42%	77.64%	76.27%	79.49%	77.57%	73.02%	72.32%	75.72%	75.49%	78.35%	75.49%	45.47%	34.77%	47.12%	36.71%	50.80%	38.92%
	F	50.316	46.421	43.815	40.641	25.098	21.735	41.057	39.669	39.469	38.989	10.666	6.001	13.343	8.888	11.992	8.153	20.159	12.044
Puts	Cst.	-0.129	0.171	0.401	0.461	-0.238	0.074	2.623***	2.977***	3.526***	3.431***	2.418***	2.823***	-0.362	-0.289	0.031	0.019	-0.434	-0.391
		(-0.222)	(0.288)	(0.691)	(0.775)	(-0.433)	(0.130)	(3.289)	(3.789)	(4.582)	(4.398)	(3.409)	(3.827)	(-0.552)	(-0.458)	(0.046)	(0.030)	(-0.670)	(-0.644)
	IV	1.127***	1.297***	1.029***	1.155***	0.998***	1.115***	0.887***	1.112***	0.720***	0.891***	0.645***	0.824***	0.571***	0.428***	0.499***	0.278*	0.486***	0.237
		(10.364)	(9.831)	(9.480)	(7.920)	(8.973)	(7.759)	(5.943)	(6.356)	(5.006)	(4.662)	(4.497)	(4.422)	(4.656)	(3.047)	(3.933)	(1.791)	(3.710)	(1.545)
	AMB^{CU}	-	-	-0.634***	-0.446**	-	-	-	-	-1.080***	-0.698**	-	-	-	-	-0.470*	-0.473**	-	-
		-	-	(-2.922)	(-2.065)	-	-	-	-	(-3.757)	(-2.467)	-	-	-	-	(-1.856)	(-2.055)	-	-
	AMB^{CU}_{SUMDEV}	-	-	-	-	0.446***	0.399***	-	-	-	-	0.836***	0.633***	-	-	-	-	0.295*	0.421***
		-	-	-	-	(3.046)	(2.658)	-	-	-	-	(4.424)	(3.253)	-	-	-	-	(1.706)	(2.626)
	SKEW	0.000	-0.002	-0.001	-0.003	0.001	-0.002	-0.015**	-0.018***	-0.017***	-0.018***	-0.013**	-0.017***	0.001	0.001	-0.000	0.001	0.002	0.002
		(0.076)	(-0.471)	(-0.215)	(-0.524)	(0.294)	(-0.342)	(-2.159)	(-2.672)	(-2.722)	(-2.819)	(-2.115)	(-2.666)	(0.175)	(0.175)	(-0.010)	(0.137)	(0.297)	(0.329)
	OI	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000*	0.000***	0.000*	0.000***	0.000*	0.000***
		(1.225)	(-0.857)	(1.396)	(-0.709)	(1.324)	(-0.772)	(1.322)	(-1.563)	(1.580)	(-1.418)	(1.531)	(-1.519)	(1.715)	(3.530)	(1.812)	(3.764)	(1.754)	(3.793)
	SDVIX	-0.027	-0.006	-0.053	-0.035	-0.085	-0.032	-0.141	-0.108	-0.185**	-0.154*	-0.248***	-0.150*	0.195***	0.163**	0.176**	0.132*	0.157**	0.135*
		(-0.409)	(-0.088)	(-0.833)	(-0.508)	(-1.287)	(-0.480)	(-1.540)	(-1.173)	(-2.186)	(-1.692)	(-2.928)	(-1.716)	(2.594)	(2.204)	(2.356)	(1.789)	(2.032)	(1.886)
	CRISISDUMMY	0.172***	0.168**	0.124**	0.138**	0.122**	0.119*	0.405***	0.412***	0.324***	0.366***	0.312***	0.334***	-0.053	-0.057	-0.088	-0.088	-0.086	-0.109
		(2.744)	(2.561)	(2.018)	(2.113)	(1.991)	(1.812)	(4.708)	(4.739)	(3.965)	(4.262)	(3.940)	(3.934)	(-0.748)	(-0.813)	(-1.223)	(-1.256)	(-1.183)	(-1.554)
	Adj R^2	78.92%	77.73%	81.00%	78.74%	81.18%	79.53%	71.49%	71.87%	76.05%	73.80%	77.54%	75.30%	43.57%	46.84%	45.50%	49.21%	45.09%	51.02%
	F	56.425	52.656	53.580	46.667	54.211	48.916	38.113	38.816	40.152	35.744	43.572	38.604	12.425	14.040	11.295	12.950	11.126	13.849

t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 7 – Variance decomposition of downside risk under low and high uncertainty

The table summarizes results from our FEVD models described in Eqs. (20-21) and compares the relative effect of ambiguity *AMB* on Eq. (19)'s variables for calls and puts over 2003-2009. Each entry in the table reports the percentage of forecast error variance of variables on the left-hand side explained by variables at the top before (**StablePeriod**) and during the crisis (**UncertainPeriod**). Entries are all convergent values in a 250-day horizon. DR represents banking downside risk. EBETA represents systematic market risk. CR represents credit risk. AMB^{PCA} is the first principal component of AMB^{CU}, $AMB^{alpha\text{-}MEP}$ and AMB^{BI}_{IYF}. IV denotes implied market volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

PANEL A: Downside Risk (DR)

CALLS (StablePeriod)	DR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX	**PUTS (StablePeriod)**	DR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX
DR	**89.959**	1.438	**3.455**	0.588	0.579	3.981	DR	**89.749**	2.623	**1.424**	2.375	0.013	3.816
IV	5.217	93.762	0.025	0.388	0.526	0.084	IV	12.756	75.204	1.778	10.127	0.052	0.082
AMB^{PCA}	23.506	8.264	49.271	5.453	11.230	2.276	AMB^{PCA}	23.616	15.259	59.091	0.398	0.280	1.357
SKEW	0.164	0.224	10.896	42.065	44.539	2.113	SKEW	5.122	17.371	22.058	27.935	13.470	14.044
OI	2.213	0.046	1.325	17.944	78.110	0.363	OI	0.049	0.025	2.384	2.049	95.339	0.155
SDVIX	0.143	0.645	0.391	0.208	1.476	97.138	SDVIX	0.069	1.904	0.810	2.240	0.421	94.556
CALLS (UncertainPeriod)	DR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX	**PUTS (UncertainPeriod)**	DR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX
DR	**78.689**	9.951	**10.176**	0.009	1.148	0.027	DR	**87.245**	6.292	**6.366**	0.002	0.089	0.007
IV	6.147	83.952	8.559	0.018	0.034	1.289	IV	6.836	90.005	1.556	0.359	0.575	0.668
AMB^{PCA}	4.966	45.846	16.694	7.484	1.645	23.365	AMB^{PCA}	36.252	11.310	30.645	2.877	2.766	16.150
SKEW	0.241	0.015	0.010	92.502	0.996	6.237	SKEW	0.436	0.036	0.063	92.012	0.706	6.747
OI	22.983	2.074	1.363	0.106	73.463	0.011	OI	17.725	8.171	0.033	0.084	73.854	0.132
SDVIX	0.956	9.248	16.678	0.622	0.105	72.391	SDVIX	3.539	6.611	33.560	0.304	0.407	55.579

PANEL B: Systematic Risk (EBETA)

CALLS (StablePeriod)	EBETA	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX	**PUTS (StablePeriod)**	EBETA	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX
EBETA	**84.545**	0.023	**2.423**	7.830	4.213	0.966	EBETA	**88.353**	0.665	**0.006**	10.097	0.054	0.825
IV	0.438	98.567	0.463	0.283	0.232	0.016	IV	0.980	86.542	1.345	10.989	0.064	0.080
AMB^{PCA}	2.186	14.226	67.569	7.828	5.554	2.636	AMB^{PCA}	12.987	15.895	61.881	7.688	0.077	1.474
SKEW	4.582	0.107	10.288	29.738	52.128	3.157	SKEW	16.803	23.792	8.513	38.075	0.187	12.631
OI	0.882	0.239	0.027	8.021	90.570	0.260	OI	1.540	0.646	0.430	7.677	89.580	0.127
SDVIX	0.650	1.060	0.069	0.293	1.274	96.654	SDVIX	0.237	3.400	0.054	2.362	0.168	93.779
CALLS (UncertainPeriod)	EBETA	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX	**PUTS (UncertainPeriod)**	EBETA	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX
EBETA	**61.130**	20.994	**15.181**	0.778	0.196	1.721	EBETA	**61.170**	26.273	**11.096**	0.997	0.005	0.460
IV	0.044	84.677	12.098	0.754	0.464	1.963	IV	0.009	92.508	4.265	0.013	0.013	3.191
AMB^{PCA}	11.556	49.326	13.794	10.892	0.334	14.098	AMB^{PCA}	13.799	41.561	13.405	14.260	0.041	16.935
SKEW	0.612	0.996	1.655	87.456	1.353	7.928	SKEW	0.472	1.078	2.054	87.422	1.008	7.965
OI	0.009	1.191	1.108	0.056	97.633	0.003	OI	0.003	5.110	0.064	0.111	94.673	0.038
SDVIX	1.519	9.784	16.855	0.007	0.015	71.819	SDVIX	1.307	6.423	22.392	0.043	0.070	69.765

PANEL C: Credit Risk (CR)

CALLS (StablePeriod)	CR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX	**PUTS (StablePeriod)**	CR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX
CR	**99.945**	0.001	**0.023**	0.014	0.004	0.014	CR	**99.601**	0.221	**0.003**	0.147	0.002	0.026
IV	0.434	98.236	0.176	0.279	0.828	0.047	IV	1.368	88.938	3.652	6.002	0.019	0.021
AMB^{PCA}	0.004	12.343	57.962	5.042	22.105	2.544	AMB^{PCA}	0.077	23.627	74.151	0.142	0.094	1.909
SKEW	0.060	0.152	9.067	53.498	35.591	1.632	SKEW	0.324	2.790	44.735	22.443	18.854	10.855
OI	0.015	0.034	6.290	17.598	75.770	0.292	OI	0.110	0.004	1.755	0.806	97.099	0.225
SDVIX	0.119	0.969	0.031	0.005	1.037	97.839	SDVIX	0.097	2.158	0.815	2.310	0.569	94.051
CALLS (UncertainPeriod)	CR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX	**PUTS (UncertainPeriod)**	CR	IV	***AMB ^{PCA}***	SKEW	OI	SDVIX
CR	**90.747**	4.673	**4.005**	0.099	0.094	0.383	CR	**91.107**	3.388	**5.037**	0.059	0.004	0.405
IV	0.212	88.720	7.943	0.016	0.262	2.848	IV	2.196	95.781	0.058	0.377	0.102	1.485
AMB^{PCA}	24.132	33.572	36.423	1.558	0.040	4.274	AMB^{PCA}	35.911	21.054	30.555	7.453	2.029	2.997
SKEW	1.404	0.251	0.281	90.278	0.937	6.850	SKEW	1.356	0.200	0.125	90.758	0.870	6.691
OI	8.684	0.035	0.563	0.254	90.395	0.069	OI	7.339	1.805	0.213	0.184	90.458	0.001
SDVIX	3.885	10.369	18.824	0.433	0.001	66.487	SDVIX	4.847	7.855	27.213	0.652	0.000	59.432

Table 8 Panel A - Ambiguity and economic activity under CU

The table summarizes our lagged univariate regressions on the effect of ambiguity AMB^{CU} on economic activity over 2003-2009. CUG stands for capacity utilization growth (production). TNPG denotes total non-farm payroll growth (employment) and CFNAI is the Chicago Fed National Activity Index (economic performance).

Dependent Variable	Production (CUG)						Employment (TNPG)						Economic Performance (CFNAI)					
Ind. Var.	$AMB^{CU}_{Call.OTM}$	$AMB^{CU}_{Call.ITM}$	$AMB^{CU}_{Put.OTM}$	$AMB^{CU}_{Put.ITM}$	$AMB^{CU}_{SUMDEV.OTM}$	$AMB^{CU}_{SUMDEV.ITM}$	$AMB^{CU}_{Call.OTM}$	$AMB^{CU}_{Call.ITM}$	$AMB^{CU}_{Put.OTM}$	$AMB^{CU}_{Put.ITM}$	$AMB^{CU}_{SUMDEV.OTM}$	$AMB^{CU}_{SUMDEV.ITM}$	$AMB^{CU}_{Call.OTM}$	$AMB^{CU}_{Call.ITM}$	$AMB^{CU}_{Put.OTM}$	$AMB^{CU}_{Put.ITM}$	$AMB^{CU}_{SUMDEV.OTM}$	$AMB^{CU}_{SUMDEV.ITM}$
Cst	14.40**	16.64***	-18.51***	-15.09***	3.98***	4.98***	4.93***	5.49***	-5.35***	-4.31***	1.88***	2.38***	2.32***	2.51***	-3.22***	-2.66***	0.50***	0.70***
	(2.46)	(2.59)	(-3.55)	(-2.80)	(3.33)	(3.30)	(2.94)	(2.66)	(-3.39)	(-2.70)	(4.92)	(5.67)	(3.00)	(2.67)	(-4.23)	(-3.47)	(3.19)	(3.77)
Ind. Var.	***-25.21*****	***-28.84*****	***35.94******	***32.21******	***-24.22******	***-23.87******	***-7.39*****	***-8.30*****	***11.89******	***10.87******	***-7.11******	***-7.76******	***-4.28******	***-4.60******	***5.98******	***5.39******	***-3.92******	***-4.01******
	(-2.40)	***(-2.53)***	***(3.72)***	***(2.93)***	***(-3.87)***	***(-3.47)***	***(-2.39)***	***(-2.29)***	***(4.20)***	***(3.35)***	***(-3.38)***	***(-3.83)***	***(-3.02)***	***(-2.77)***	***(4.35)***	***(3.45)***	***(-4.25)***	***(-4.40)***
Adj R^2	13.15%	13.15%	13.55%	17.23%	18.49%	20.90%	23.11%	22.24%	30.70%	40.23%	32.19%	44.76%	32.51%	28.53%	32.04%	40.65%	40.54%	49.46%
F	12.06	12.05	12.44	16.20	17.56	20.29	22.94	21.88	33.34	50.13	35.66	60.15	36.16	30.14	35.41	50.99	50.78	72.44

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 8 Panel B - Ambiguity and economic activity under α-MEP and EUUP

The table summarizes our lagged univariate regressions on the effect of ambiguity ($AMB^{alpha\text{-}MEP}$ and AMB^{BI}_{IYF}) on economic activity over 2003-2009. CUG stands for capacity utilization growth (production). TNPG denotes total non-farm payroll growth (employment) and CFNAI is the Chicago Fed National Activity Index (economic performance).

Dependent Variable	Production (CUG)							Employment (TNPG)							Economic Performance (CFNAI)						
Ind. Var.	$AMB^{alpha}_{Call.OTM}$	$AMB^{alpha}_{Call.ITM}$	$AMB^{alpha}_{Put.OTM}$	$AMB^{alpha}_{Put.ITM}$	$AMB^{alpha}_{SUM.OTM}$	$AMB^{alpha}_{SUM.ITM}$	AMB^{BI}_{IYF}	$AMB^{alpha}_{Call.OTM}$	$AMB^{alpha}_{Call.ITM}$	$AMB^{alpha}_{Put.OTM}$	$AMB^{alpha}_{Put.ITM}$	$AMB^{alpha}_{SUM.OTM}$	$AMB^{alpha}_{SUM.ITM}$	AMB^{BI}_{IYF}	$AMB^{alpha}_{Call.OTM}$	$AMB^{alpha}_{Call.ITM}$	$AMB^{alpha}_{Put.OTM}$	$AMB^{alpha}_{Put.ITM}$	$AMB^{alpha}_{SUM.OTM}$	$AMB^{alpha}_{SUM.ITM}$	AMB^{BI}_{IYF}
Cst	15.23**	16.95*	7.09***	18.37***	14.02***	23.76**	1.82	5.31***	5.36**	3.07***	7.10***	5.55***	8.41***	1.45***	1.98**	2.33**	1.05***	3.04***	2.28***	3.77***	0.19
	(2.29)	(1.77)	(3.31)	(2.72)	(2.14)	(1.55)	(1.01)	(3.25)	(1.99)	(7.60)	(5.49)	(7.60)	(5.49)	(5.16)	(2.57)	(2.04)	(5.55)	(4.79)	(7.60)	(5.49)	(1.24)
Ind. Var.	***-19.69*****	***-21.99****	***-18.25******	***-26.13******	***-23.63******	***-31.53******	***-3.36*****	***-5.99******	***-6.07****	***-5.93******	***-8.97******	***-8.03******	***-10.16******	***-1.18******	***-2.82******	***-3.24*****	***-3.04******	***-4.50******	***-4.06******	***-5.18******	***-0.58******
	(-2.33)	***(-1.83)***	***(-3.33)***	***(-2.75)***	***(-2.90)***	***(-2.59)***	***(-2.46)***	***(-2.90)***	***(-1.86)***	***(-6.03)***	***(-4.92)***	***(-5.23)***	***(-3.88)***	***(-5.74)***	***(-2.81)***	***(-2.29)***	***(-6.33)***	***(-4.95)***	***(-5.49)***	***(-4.17)***	***(-5.08)***
Adj R^2	4.49%	4.04%	22.27%	12.69%	3.12%	-6.46%	11.39%	9.24%	6.72%	47.53%	31.14%	47.53%	31.14%	29.67%	8.30%	8.14%	51.62%	32.29%	47.53%	31.14%	29.78%
F	4.48	4.07	21.92	11.61	1.31	-8.99	10.39	8.43	6.26	67.12	34.02	67.12	34.02	31.79	7.61	7.47	78.88	35.82	67.12	34.02	31.96

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table 8 Panel C - Systemic banking risk and economic activity under CU

The table summarizes our lagged univariate regressions on the effect of systemic banking risk (SBR) on economic activity over 2003-2009. CUG stands for capacity utilization growth (production). TNPG denotes total non-farm payroll growth (employment) and CFNAI is the Chicago Fed National Activity Index (economic performance). Raw SBR are direct and raw measures of systemic risk. SBR^{CU}call, SBR^{CU}put and SBR^{CU}_{SUMDEV} are predicted systemic banking risk measures based on Eq. (19) under CU. DR, EBETA and CR are as defined before.

	Dependent Variable	Production (CUG)							Employment (TNPG)							Economic Performance (CFNAI)						
	Ind. Var.	Raw SBR	SBR^{CU}_{OTMC}	SBR^{CU}_{ITMC}	SBR^{CU}_{OTMP}	SBR^{CU}_{ITMP}	$SBR^{CU}_{SUMDEV,OTM}$	$SBR^{CU}_{SUMDEV,ITM}$	Raw SBR	SBR^{CU}_{OTMC}	SBR^{CU}_{ITMC}	SBR^{CU}_{OTMP}	SBR^{CU}_{ITMP}	$SBR^{CU}_{SUMDEV,OTM}$	$SBR^{CU}_{SUMDEV,ITM}$	Raw SBR	SBR^{CU}_{OTMC}	SBR^{CU}_{ITMC}	SBR^{CU}_{OTMP}	SBR^{CU}_{ITMP}	$SBR^{CU}_{SUMDEV,OTM}$	$SBR^{CU}_{SUMDEV,ITM}$
DR	Cst	4.90***	4.49***	4.50***	4.89***	4.50***	4.82***	4.56***	2.19***	2.49***	2.52***	2.53***	2.52***	2.48***	2.51***	0.58***	0.68***	0.68***	0.69***	0.68***	0.69***	0.69***
		(4.88)	(3.93)	(3.82)	(4.76)	(3.82)	(4.43)	(4.13)	(9.10)	(12.66)	(13.59)	(15.48)	(13.59)	(12.34)	(14.38)	(6.90)	(6.09)	(6.13)	(8.77)	(6.13)	(7.27)	(7.23)
	Ind. Var.	-18.03***	-17.17***	-17.19***	-18.35***	-17.19***	-18.17***	-17.36***	-5.38***	-6.33***	-6.40***	-6.47***	-6.40***	-6.33***	-6.39***	-2.72***	-3.05***	-3.06***	-3.08***	-3.06***	-3.09***	-3.07***
		(-8.11)	(-5.27)	(-5.33)	(-6.76)	(-5.33)	(-6.33)	(-5.78)	(-7.51)	(-11.73)	(-12.44)	(-19.00)	(-12.44)	(-13.07)	(-13.80)	(-11.92)	(-8.27)	(-8.78)	(-15.03)	(-8.78)	(-11.27)	(-10.39)
	Adj R^2	43.66%	27.35%	27.13%	32.67%	27.13%	31.07%	28.25%	77.41%	75.27%	76.17%	81.55%	76.17%	75.87%	77.30%	81.44%	71.91%	71.62%	76.09%	71.62%	74.31%	73.22%
	F	57.58	28.48	28.18	36.43	28.18	33.90	29.74	251.22	223.14	234.35	323.70	234.35	230.51	249.52	321.30	187.86	185.22	233.35	185.22	212.11	200.56
EBETA	Cst	13.14***	16.36***	16.68***	18.30***	16.68***	17.67***	17.11***	4.85***	6.97***	6.92***	7.24***	6.92***	6.88***	7.09***	1.89***	2.84***	2.80***	2.91***	2.80***	2.84***	2.87***
		(4.84)	(4.62)	(4.47)	(5.22)	(4.47)	(5.31)	(4.80)	(4.93)	(9.13)	(9.01)	(9.05)	(9.01)	(8.07)	(10.06)	(5.93)	(7.90)	(7.67)	(8.30)	(7.67)	(7.94)	(8.65)
	Ind. Var.	-11.75***	-14.27***	-14.52***	-15.83***	-14.52***	-15.33***	-14.87***	-3.67***	-5.34***	-5.30***	-5.56***	-5.30***	-5.28***	-5.43***	-1.83***	-2.58***	-2.55***	-2.63***	-2.55***	-2.58***	-2.60***
		(-5.02)	(-4.71)	(-4.60)	(-5.40)	(-4.60)	(-5.56)	(-4.95)	(-4.10)	(-7.92)	(-7.90)	(-7.98)	(-7.90)	(-7.17)	(-8.93)	(-6.18)	(-8.09)	(-8.03)	(-8.71)	(-8.03)	(-8.39)	(-9.06)
	Adj R^2	22.83%	24.17%	25.81%	30.27%	25.81%	28.87%	26.93%	44.94%	68.86%	69.65%	75.26%	69.65%	68.97%	72.83%	45.79%	65.95%	66.10%	69.27%	66.10%	67.93%	68.60%
	F	22.60	24.27	26.40	32.70	26.40	30.63	27.90	60.59	162.41	168.54	223.03	168.54	163.22	196.65	62.66	142.37	143.31	165.54	143.31	155.62	160.46
CR	Cst	1.24	2.16**	2.15**	2.51***	2.15**	2.33***	2.18**	1.11***	1.42***	1.71***	1.71***	1.71***	1.39***	1.69***	0.03	0.22**	0.32***	0.31***	0.32***	0.21**	0.31***
		(1.28)	(2.48)	(2.15)	(3.01)	(2.15)	(2.86)	(2.27)	(3.50)	(5.59)	(7.73)	(8.31)	(7.73)	(5.56)	(7.70)	(0.23)	(2.22)	(3.79)	(4.52)	(3.79)	(2.24)	(3.85)
	Ind. Var.	-19.71***	-26.74***	-26.86***	-29.66***	-26.86***	-28.14***	-27.10***	-5.99***	-8.39***	-10.50***	-10.59***	-10.50***	-8.18***	-10.32***	-3.02***	-4.41***	-5.14***	-5.17***	-5.14***	-4.38***	-5.09***
		(-5.75)	(-3.98)	(-3.78)	(-5.20)	(-3.78)	(-4.64)	(-3.82)	(-8.04)	(-4.59)	(-5.30)	(-7.72)	(-5.30)	(-4.97)	(-5.26)	(-8.48)	(-6.20)	(-6.63)	(-9.95)	(-6.63)	(-6.82)	(-6.55)
	Adj R^2	25.12%	22.63%	17.64%	25.35%	17.64%	26.27%	18.85%	46.64%	45.00%	55.61%	65.48%	55.61%	44.50%	56.21%	48.79%	51.38%	54.89%	64.07%	54.89%	52.62%	56.27%
	F	25.48	22.35	16.63	25.79	16.63	27.02	17.96	64.80	60.72	92.45	139.49	92.45	59.52	94.70	70.55	78.14	89.83	131.18	89.83	82.06	94.95

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table S1 – Ambiguity and systemic bank risk under CU and α-MEP

The table summarizes our daily panel regression results on the effect of ambiguity on systemic bank risks DR and EBETA over 2003-2009. IV is the option implied volatility per bank. $AMB^{CU,B}$ and $AMB^{alpha,B}$ are the ambiguity scores per bank under CU and α-MEP. AMB^{CU}_{SUMDEV} and AMB^{alpha}_{SUM} capture the degree of ambiguity in the options market per bank under CU and α-MEP. SKEW is the CBOE SKEW index. OI is the option open-interest per bank. SDVIX is the volatility of VIX. Size is the natural logarithm of the bank's market capitalization. The panel regressions are specified with cross-sectional and time fixed-effects.

		Overall Period (2003-2009)																			
		Downside Risk (DR)										Systematic Risk (EBETA)									
		OTM	OTM	OTM	OTM	OTM	ITM	ITM	ITM	ITM	ITM	OTM	OTM	OTM	OTM	OTM	ITM	ITM	ITM	ITM	ITM
Calls	Cst.	-1.457	-1.625	-1.684	-1.642	-1.594	1.021	0.667	0.659	0.704	0.659	-0.355	-0.678	-1.024	-0.974	-0.968	2.183*	1.616	1.275	1.498	1.085
		(-1.276)	(-1.406)	(-1.437)	(-1.447)	(-1.400)	(0.820)	(0.554)	(0.527)	(0.594)	(0.559)	(-0.380)	(-0.754)	(-1.212)	(-1.145)	(-1.140)	(1.883)	(1.564)	(1.209)	(1.472)	(1.094)
	IV	1.423***	1.405***	1.379***	1.430***	1.405***	1.078***	1.059***	1.035***	1.109***	1.078***	1.555***	1.520***	1.427***	1.581***	1.477***	1.184***	1.154***	1.076***	1.250***	1.183***
		(4.181)	(4.187)	(4.200)	(4.251)	(4.163)	(3.655)	(3.719)	(3.647)	(3.861)	(3.735)	(4.795)	(4.796)	(4.650)	(5.108)	(4.726)	(4.161)	(4.284)	(3.985)	(4.746)	(4.477)
	AMB^{CU}	-	0.171***	-	-	-	-	0.335***	-	-	-	-	0.331***	-	-	-	-	0.537***	-	-	-
		-	(2.867)	-	-	-	-	(3.317)	-	-	-	-	(4.396)	-	-	-	-	(4.760)	-	-	-
	AMB^{CU}_{SUMDEV}	-	-	0.638***	-	-	-	-	0.793***	-	-	-	-	1.888***	-	-	-	-	1.990***	-	-
		-	-	(2.687)	-	-	-	-	(2.948)	-	-	-	-	(7.208)	-	-	-	-	(7.010)	-	-
	AMB^{alpha}	-	-	-	0.118***	-	-	-	-	0.268***	-	-	-	-	0.395***	-	-	-	-	0.579***	-
		-	-	-	(3.038)	-	-	-	-	(3.573)	-	-	-	-	(8.671)	-	-	-	-	(7.411)	-
	AMB^{alpha}_{SUM}	-	-	-	-	0.115***	-	-	-	-	0.237***	-	-	-	-	0.517***	-	-	-	-	0.719***
		-	-	-	-	(3.475)	-	-	-	-	(3.199)	-	-	-	-	(9.847)	-	-	-	-	(7.919)
	SKEW	-0.008**	-0.008**	-0.008**	-0.008**	-0.008**	-0.012**	-0.011**	-0.011**	-0.012**	-0.011**	-0.007	-0.005	-0.006*	-0.006	-0.005	-0.012***	-0.011***	-0.010***	-0.011***	-0.010**
		(-2.219)	(-2.156)	(-2.229)	(-2.186)	(-2.160)	(-2.340)	(-2.361)	(-2.330)	(-2.368)	(-2.306)	(-1.602)	(-1.375)	(-1.678)	(-1.445)	(-1.214)	(-2.741)	(-2.811)	(-2.786)	(-2.805)	(-2.494)
	OI	0.058	0.054	0.053	0.058	0.055	0.017	0.010	0.009	0.011	0.012	0.091**	0.083**	0.077**	0.092**	0.077**	0.089***	0.078***	0.068***	0.076***	0.074***
		(1.562)	(1.493)	(1.481)	(1.578)	(1.515)	(0.817)	(0.530)	(0.452)	(0.565)	(0.608)	(2.284)	(2.213)	(2.260)	(2.414)	(2.123)	(4.013)	(4.015)	(3.982)	(3.949)	(3.771)
	SDVIX	0.021	0.005	-0.023	0.008	-0.000	0.110	0.080	0.046	0.082	0.083	0.052	0.023	-0.078	0.011	-0.042	0.199**	0.151**	0.039	0.139*	0.118
		(0.335)	(0.086)	(-0.341)	(0.136)	(-0.002)	(1.608)	(1.223)	(0.661)	(1.256)	(1.289)	(0.666)	(0.289)	(-1.045)	(0.136)	(-0.566)	(2.487)	(1.987)	(0.514)	(1.877)	(1.623)
	SIZE	0.150	0.155	0.166	0.155	0.155	0.010	0.027	0.037	0.024	0.026	0.075	0.085	0.123	0.092	0.101	-0.097	-0.068	-0.028	-0.066	-0.048
		(1.337)	(1.389)	(1.467)	(1.398)	(1.401)	(0.091)	(0.259)	(0.340)	(0.229)	(0.249)	(0.881)	(1.027)	(1.563)	(1.166)	(1.274)	(-1.070)	(-0.822)	(-0.347)	(-0.805)	(-0.595)
	R-squared	32.10%	**32.40%**	**32.80%**	**32.30%**	**32.30%**	25.90%	**26.90%**	**27.00%**	**26.80%**	**26.40%**	49.40%	**50.90%**	**56.60%**	**52.80%**	**55.00%**	42.30%	**45.30%**	**50.20%**	**47.10%**	**47.40%**
	F	19.61	17.67	19.40	20.05	16.55	19.87	17.16	18.15	17.28	16.94	18.22	15.88	19.40	25.83	28.52	15.21	13.85	17.77	18.62	25.21
Puts	Constant	-2.359**	-2.337**	-2.457**	-2.449**	-2.439**	-1.603*	-1.669*	-1.788*	-1.877**	-1.845**	-1.631**	-1.532**	-2.003***	-2.028***	-2.099***	-0.286	-0.574	-0.923	-1.219	-1.253*
		(-2.076)	(-2.071)	(-2.113)	(-2.147)	(-2.133)	(-1.802)	(-1.835)	(-1.882)	(-2.029)	(-1.971)	(-2.158)	(-2.094)	(-2.831)	(-2.843)	(-2.922)	(-0.393)	(-0.827)	(-1.418)	(-1.638)	(-1.754)
	IV	1.606***	1.598***	1.570***	1.585***	1.593***	1.524***	1.525***	1.477***	1.527***	1.517***	1.740***	1.703***	1.603***	1.644***	1.659***	1.780***	1.784***	1.619***	1.792***	1.751***
		(5.239)	(5.267)	(5.317)	(5.188)	(5.214)	(5.141)	(5.154)	(5.250)	(5.130)	(5.135)	(8.093)	(8.115)	(7.713)	(7.701)	(7.722)	(7.790)	(7.995)	(7.523)	(7.784)	(7.667)
	AMB^{CU}	-	-0.107*	-	-	-	-	-0.117*	-	-	-	-	-0.475***	-	-	-	-	-0.511***	-	-	-
		-	(-1.716)	-	-	-	-	(-1.669)	-	-	-	-	(-4.929)	-	-	-	-	(-5.918)	-	-	-
	AMB^{CU}_{SUMDEV}	-	-	0.432**	-	-	-	-	0.502**	-	-	-	-	1.640***	-	-	-	-	1.732***	-	-
		-	-	(2.238)	-	-	-	-	(2.264)	-	-	-	-	(6.642)	-	-	-	-	(6.217)	-	-
	AMB^{alpha}	-	-	-	0.074***	-	-	-	-	0.129***	-	-	-	-	0.327***	-	-	-	-	0.439***	-
		-	-	-	(4.255)	-	-	-	-	(4.672)	-	-	-	-	(9.995)	-	-	-	-	(10.843)	-
	AMB^{alpha}_{SUM}	-	-	-	-	0.080***	-	-	-	-	0.168***	-	-	-	-	0.469***	-	-	-	-	0.671***
		-	-	-	-	(3.667)	-	-	-	-	(3.675)	-	-	-	-	(10.840)	-	-	-	-	(10.880)
	SKEW	-0.006*	-0.006*	-0.006*	-0.005	-0.005*	-0.008**	-0.008**	-0.008**	-0.007**	-0.008**	-0.004	-0.004	-0.003	-0.002	-0.002	-0.006	-0.005	-0.005	-0.004	-0.005
		(-1.726)	(-1.733)	(-1.727)	(-1.622)	(-1.653)	(-2.349)	(-2.315)	(-2.371)	(-2.197)	(-2.292)	(-0.971)	(-1.031)	(-1.004)	(-0.463)	(-0.534)	(-1.524)	(-1.391)	(-1.626)	(-1.065)	(-1.293)
	OI	0.032	0.031	0.027	0.027	0.029	0.036*	0.035*	0.036*	0.033*	0.035*	0.091***	0.088***	0.074***	0.073***	0.075***	0.034	0.030	0.031	0.023	0.030
		(1.353)	(1.343)	(1.250)	(1.225)	(1.269)	(1.803)	(1.743)	(1.807)	(1.657)	(1.777)	(3.248)	(3.371)	(3.547)	(3.088)	(3.092)	(1.410)	(1.332)	(1.612)	(1.003)	(1.356)
	SDVIX	-0.017	-0.026	-0.046	-0.039	-0.032	-0.025	-0.037	-0.058	-0.039	-0.040	0.016	-0.024	-0.093	-0.079	-0.070	0.007	-0.048	-0.109	-0.042	-0.052
		(-0.265)	(-0.396)	(-0.651)	(-0.586)	(-0.482)	(-0.390)	(-0.564)	(-0.822)	(-0.602)	(-0.601)	(0.229)	(-0.352)	(-1.356)	(-1.169)	(-1.021)	(0.089)	(-0.676)	(-1.545)	(-0.587)	(-0.716)
	SIZE	0.223**	0.227**	0.232**	0.230**	0.227**	0.181**	0.191**	0.192**	0.195**	0.190**	0.148**	0.166***	0.181***	0.178***	0.170***	0.122*	0.166***	0.159***	0.169***	0.156**
		(2.233)	(2.251)	(2.266)	(2.298)	(2.266)	(2.002)	(2.048)	(2.054)	(2.121)	(2.067)	(2.211)	(2.595)	(2.875)	(2.753)	(2.610)	(1.930)	(2.701)	(2.647)	(2.596)	(2.437)
	R-squared	35.90%	**35.90%**	**36.20%**	**36.10%**	**36.00%**	33.90%	**34.10%**	**34.40%**	**34.20%**	**34.20%**	56.10%	**57.90%**	**61.30%**	**60.50%**	**60.60%**	53.80%	**57.00%**	**59.70%**	**57.30%**	**58.30%**
	F	26.90	22.74	22.01	26.56	23.73	27.48	25.81	24.19	23.09	24.32	18.65	17.78	20.11	31.47	33.51	21.78	19.82	21.06	25.88	27.41

Cross-sectional dependence robust t-statistics based on Driscoll and Kraay (1998) are reported in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table S2 – Ambiguity and systemic banking risk (1999-2015)

The table summarizes our regression results on the effect of ambiguity on systemic banking risk DR, DBETA (downside beta used herein to partly mitigate endogeneity and multicollinearity issues associated with the AMB^{BI}-EBETA relationship) and CR over 1999-2015. IV is the implied volatility of the IYF options, AMB^{BI}_{SPX} is the ambiguity indicator under EUUP based on Eq. (6), SKEW is the CBOE SKEW index, OI is the option interest of IYF options, SDVIX is the standard deviation of VIX, and NBER is the National Bureau of Economic Research recession indicator.

	Overall Period								
	DR			DBETA			CR		
Cst.	-0.100	-0.016	-0.076	-0.209	0.040	-0.061	-0.402**	-0.154	-0.228
	(-0.947)	(-0.137)	(-0.730)	(-0.979)	(0.160)	(-0.248)	(-2.362)	(-1.014)	(-1.571)
IV	0.827***	0.855***	0.733***	1.219***	1.302***	1.096***	0.365***	0.448***	0.296**
	(14.634)	(13.616)	(13.912)	(11.544)	(11.659)	(9.405)	(3.457)	(3.695)	(2.415)
AMB^{BI}_{SPX}	-	***0.016*****	***0.011****	-	***0.047*****	***0.040****	-	***0.047******	***0.042******
	-	***(2.128)***	***(1.649)***	-	***(1.964)***	***(1.661)***	-	***(3.589)***	***(3.199)***
SKEW	0.000	0.000	0.000	0.006***	0.004	0.005**	0.003**	0.000	0.001
	(0.542)	(-0.417)	(0.306)	(3.618)	(1.607)	(2.193)	(2.360)	(0.215)	(1.015)
OI	0.000	0.000	0.000	0.000***	0.000***	0.000***	0.000**	0.000*	0.000*
	(1.181)	(1.312)	(1.381)	(5.968)	(6.167)	(6.301)	(-2.044)	(-1.734)	(-1.743)
SDVIX	0.009	0.008	0.008	0.003	0.001	0.001	0.043***	0.042***	0.041***
	(1.209)	(1.164)	(1.149)	(0.231)	(0.121)	(0.054)	(3.873)	(3.951)	(4.039)
NBER	-	-	0.093***	-	-	0.158***	-	-	0.117***
	-	-	(3.157)	-	-	(2.843)	-	-	(4.831)
Adj R^2	59.98%	**60.21%**	**62.34%**	41.76%	**42.27%**	**43.74%**	32.37%	**34.59%**	**38.05%**
F	1532.256	1238.135	1128.729	733.744	599.577	530.594	490.002	433.240	419.426

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table S3 - Monthly effect of ambiguity on systemic banking risk under α-MEP and EUUP

The table summarizes our 2003-2009 monthly regression results based on Eq. (19). This model is compared to the multivariate structure without the *AMB* term. DR stands for systemic banks' downside risk, EBETA is systemic banks' market beta risk, and CR is systemic banks' credit risk. $AMB^{alpha\text{-}MEP}$ and $AMB^{alpha\text{-}MEP}_{SUM}$ are the elicited ambiguity indicators under α-MEP based on Eqs. (16-18). AMB^{BI}_{IYF} is the ambiguity indicator from IYF based on Eq. (6). IV denotes implied volatility. SKEW is the CBOE SKEW index. OI denotes open-interest information and SDVIX is the volatility of VIX.

		Overall Period																					
		Downside Risk (DR)								Systematic Risk (EBETA)						Credit Risk (CR)							
		1.OTM	2.ITM	3.OTM	4.ITM	5.OTM	6.ITM	7.OTM	8.ITM	9.OTM	10.ITM	11.OTM	12.ITM	13.OTM	14.ITM	15.OTM	16.ITM	17.OTM	18.ITM	19.OTM	20.ITM	21.OTM	22.ITM
Calls	Cst.	0.119	0.209	-0.005	0.227	0.050	0.093	1.100*	1.143*	2.830***	2.806***	2.354***	2.177***	2.377***	2.054***	-0.195	0.076	-0.240	0.110	-0.301	-0.140	1.848***	2.118***
		(0.197)	(0.338)	(-0.009)	(0.372)	(0.086)	(0.153)	(1.687)	(1.764)	(3.676)	(3.627)	(2.963)	(2.788)	(3.105)	(2.586)	(-0.305)	(0.110)	(-0.390)	(0.168)	(-0.510)	(-0.215)	(3.459)	(3.848)
	IV	1.212***	1.131***	1.301***	1.096***	1.117***	1.079***	0.956***	0.863***	1.089***	0.983***	1.063***	0.959***	1.001***	0.885***	0.366***	0.472***	0.311**	0.406***	0.219*	0.375***	-0.169	-0.115
		(9.512)	(9.302)	(9.891)	(9.010)	(8.612)	(8.814)	(6.542)	(6.115)	(6.697)	(6.458)	(6.643)	(6.547)	(6.218)	(5.881)	(2.707)	(3.455)	(2.353)	(3.096)	(1.674)	(2.864)	(-1.409)	(-0.957)
	AMB^{alpha}	-	-	0.151*	0.171*	-	-	-	-	-	-	0.434*	0.707***	-	-	-	-	0.229**	0.324***	-	-	-	-
		-	-	(1.772)	(1.695)	-	-	-	-	-	-	(1.921)	(2.616)	-	-	-	-	(2.513)	(2.985)	-	-	-	-
	AMB^{alpha}_{SUM}	-	-	-	-	0.262**	0.254*	-	-	-	-	-	-	0.438**	0.736***	-	-	-	-	0.403***	0.478***	-	-
		-	-	-	-	(2.366)	(1.886)	-	-	-	-	-	-	(2.453)	(2.650)	-	-	-	-	(3.605)	(3.311)	-	-
	AMB^{BI}_{IYF}	-	-	-	-	-	-	0.080***	0.082***	-	-	-	-	-	-	-	-	-	-	-	-	0.167***	0.179***
		-	-	-	-	-	-	(3.089)	(3.230)	-	-	-	-	-	-	-	-	-	-	-	-	(7.851)	(8.310)
	SKEW	-0.001	-0.002	-0.001	-0.004	-0.002	-0.003	-0.010*	-0.010*	-0.016**	-0.016**	-0.015**	-0.016**	-0.014**	-0.014**	0.000	-0.003	-0.001	-0.005	-0.000	-0.003	-0.017***	-0.020***
		(-0.289)	(-0.436)	(-0.296)	(-0.684)	(-0.360)	(-0.528)	(-1.749)	(-1.824)	(-2.479)	(-2.448)	(-2.352)	(-2.480)	(-2.246)	(-2.233)	(0.030)	(-0.438)	(-0.167)	(-0.893)	(-0.061)	(-0.617)	(-3.726)	(-4.172)
	OI	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	0.000***	0.000	0.000***	0.000	0.000***	0.000	0.000***	0.000
		(0.264)	(0.474)	(-0.280)	(0.257)	(-0.090)	(0.203)	(-0.579)	(0.234)	(-0.856)	(0.685)	(-0.934)	(0.678)	(-1.019)	(0.327)	(3.986)	(1.247)	(3.637)	(0.919)	(3.721)	(0.839)	(3.096)	(1.059)
	SDVIX	-0.000	-0.012	0.035	0.040	0.052	0.033	-0.039	-0.059	-0.107	-0.130	-0.129	-0.158*	-0.143	-0.171*	0.168**	0.218***	0.244***	0.316***	0.250***	0.303***	0.089	0.116**
		(-0.007)	(-0.165)	(0.475)	(0.514)	(0.726)	(0.444)	(-0.573)	(-0.846)	(-1.185)	(-1.440)	(-1.453)	(-1.809)	(-1.623)	(-1.942)	(2.253)	(2.688)	(3.125)	(3.785)	(3.438)	(3.784)	(1.597)	(1.974)
	CRISISDUMMY	0.193***	0.198***	0.170***	0.188***	0.138**	0.169**	0.234***	0.235***	0.413***	0.409***	0.395***	0.370***	0.345***	0.368***	-0.019	0.000	-0.047	-0.020	-0.105	-0.055	0.067	0.081
		(2.969)	(2.956)	(2.702)	(2.820)	(2.046)	(2.493)	(3.731)	(3.679)	(4.981)	(4.865)	(4.813)	(4.507)	(4.060)	(4.493)	(-0.279)	(0.005)	(-0.705)	(-0.280)	(-1.543)	(-0.760)	(1.292)	(1.494)
	Adj R^2	76.92%	75.42%	**78.64%**	**76.07%**	**78.36%**	**76.30%**	**79.46%**	**78.38%**	73.02%	72.32%	**74.03%**	**74.48%**	**74.85%**	**74.54%**	45.47%	34.77%	**49.37%**	**41.48%**	**53.55%**	**43.00%**	**70.98%**	**67.16%**
	F	50.316	46.421	45.806	40.212	45.655	40.710	48.709	45.713	41.057	39.669	36.163	36.999	37.706	37.113	13.343	8.888	13.029	9.742	15.217	10.304	31.162	26.221
Puts	Cst.	-0.129	0.171	-0.192	-0.140	-0.158	0.052	0.586	1.035	2.623***	2.977***	2.373***	2.271***	2.221***	2.097***	-0.362	-0.289	-0.454	-0.711	-0.417	-0.447	1.774***	1.836***
		(-0.222)	(0.288)	(-0.343)	(-0.235)	(-0.276)	(0.090)	(0.892)	(1.559)	(3.289)	(3.789)	(3.023)	(2.864)	(2.790)	(2.646)	(-0.552)	(-0.458)	(-0.742)	(-1.149)	(-0.677)	(-0.748)	(3.115)	(3.385)
	IV	1.127***	1.297***	0.992***	1.250***	1.050***	1.255***	0.926***	1.045***	0.887***	1.112***	0.806***	1.012***	0.812***	1.015***	0.571***	0.428***	0.376***	0.364***	0.426***	0.372***	-0.030	-0.190
		(10.364)	(9.831)	(8.459)	(9.600)	(9.153)	(9.746)	(6.553)	(6.499)	(5.943)	(6.356)	(5.378)	(5.923)	(5.450)	(6.054)	(4.656)	(3.047)	(2.930)	(2.686)	(3.452)	(2.782)	(-0.242)	(-1.444)
	AMB^{alpha}	-	-	0.282**	0.304**	-	-	-	-	-	-	0.282**	0.563***	-	-	-	-	0.409***	0.413***	-	-	-	-
		-	-	(2.552)	(2.194)	-	-	-	-	-	-	(2.187)	(2.758)	-	-	-	-	(3.387)	(2.864)	-	-	-	-
	AMB^{alpha}_{SUM}	-	-	-	-	0.202*	0.305**	-	-	-	-	-	-	0.418**	0.841***	-	-	-	-	0.379***	0.406***	-	-
		-	-	-	-	(1.852)	(2.399)	-	-	-	-	-	-	(2.240)	(3.118)	-	-	-	-	(3.229)	(3.072)	-	-
	AMB^{BI}_{IYF}	-	-	-	-	-	-	0.057**	0.069**	-	-	-	-	-	-	-	-	-	-	-	-	0.169***	0.170***
		-	-	-	-	-	-	(2.152)	(2.543)	-	-	-	-	-	-	-	-	-	-	-	-	(7.416)	(7.654)
	SKEW	0.000	-0.002	0.001	-0.001	-0.000	-0.003	-0.006	-0.010*	-0.015**	-0.018***	-0.013*	-0.015**	-0.013*	-0.016**	0.001	0.001	0.002	0.003	0.000	-0.000	-0.017***	-0.017***
		(0.076)	(-0.471)	(0.168)	(-0.234)	(-0.002)	(-0.648)	(-0.998)	(-1.695)	(-2.159)	(-2.672)	(-1.956)	(-2.308)	(-1.959)	(-2.460)	(0.175)	(0.175)	(0.306)	(0.505)	(0.048)	(-0.022)	(-3.469)	(-3.621)
	OI	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000*	0.000	-0.000*	0.000*	0.000***	0.000	0.000***	0.000	0.000***	0.000**	0.000***
		(1.225)	(-0.857)	(1.049)	(-1.093)	(0.909)	(-1.331)	(1.220)	(-1.359)	(1.322)	(-1.563)	(0.958)	(-1.697)	(1.010)	(-1.774)	(1.715)	(3.530)	(1.543)	(3.408)	(1.246)	(3.079)	(2.166)	(3.231)
	SDVIX	-0.027	-0.006	-0.005	0.013	0.013	0.055	-0.056	-0.037	-0.141	-0.108	-0.173*	-0.146	-0.175*	-0.151*	0.195***	0.163**	0.227***	0.189***	0.271***	0.244***	0.111*	0.087
		(-0.409)	(-0.088)	(-0.079)	(0.187)	(0.185)	(0.760)	(-0.839)	(-0.547)	(-1.540)	(-1.173)	(-1.911)	(-1.639)	(-1.940)	(-1.721)	(2.594)	(2.204)	(3.213)	(2.658)	(3.638)	(3.267)	(1.921)	(1.561)
	CRISISDUMMY	0.172***	0.168**	0.090	0.116*	0.132**	0.135**	0.205***	0.215***	0.405***	0.412***	0.330***	0.373***	0.342***	0.364***	-0.053	-0.057	-0.172**	-0.127*	-0.128*	-0.100	0.045	0.059
		(2.744)	(2.561)	(1.317)	(1.711)	(2.024)	(2.086)	(3.251)	(3.269)	(4.708)	(4.739)	(3.650)	(4.441)	(3.879)	(4.367)	(-0.748)	(-0.813)	(-2.300)	(-1.791)	(-1.818)	(-1.487)	(0.821)	(1.100)
	Adj R^2	78.92%	77.73%	**80.48%**	**78.90%**	**79.64%**	**79.17%**	**79.98%**	**79.36%**	71.49%	71.87%	**72.97%**	**74.33%**	**73.06%**	**75.03%**	43.57%	46.84%	**51.00%**	**51.86%**	**50.35%**	**52.63%**	**68.34%**	**71.02%**
	F	56.425	52.656	51.864	47.108	49.248	47.862	50.268	48.434	38.113	38.816	34.298	36.713	34.446	38.055	12.425	14.040	13.838	14.288	13.507	14.705	27.624	31.231

t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table S4 - Systemic banking risk and economic activity under α-MEP and EUUP

The table summarizes our lagged univariate regressions on the effect of systemic banking risk (SBR) on economic activity over 2003-2009. CUG stands for capacity utilization growth (production). TNPG denotes total non-farm payroll growth (employment) and CFNAI is the Chicago Fed National Activity Index (economic performance). RawSBR are direct and raw measures of systemic risk. SBR^{alpha}_{call}, SBR^{alpha}_{put} and SBR^{alpha}_{SUM} and SBR^{AMB_BI} are predicted systemic banking risk measures based on Eq. (19) under α-MEP and EUUP. DR, EBETA and CR are as defined before.

	Dependent Variable	Production (CUG)										
	Ind. Var.	Raw SBR	SBR^{alpha}_{OTMC}	SBR^{alpha}_{ITMC}	SBR^{alpha}_{OTMP}	SBR^{alpha}_{ITMP}	$SBR^{alpha}_{SUM,OTM}$	$SBR^{alpha}_{SUM,ITM}$	$SBR^{AMB\_BI}_{OTMC}$	$SBR^{AMB\_BI}_{ITMC}$	$SBR^{AMB\_BI}_{OTMP}$	$SBR^{AMB\_BI}_{ITMP}$
DR	Cst	4.90***	4.14***	4.39***	4.67***	4.29***	4.62***	4.51***	4.46***	4.61***	4.82***	4.53***
		(4.88)	(3.48)	(3.70)	(4.08)	(3.71)	(4.05)	(3.88)	(3.84)	(3.96)	(4.51)	(4.08)
	Ind. Var.	***-18.03****	***-17.16****	***-17.88****	***-18.92****	***-17.40****	***-17.53****	***-17.22****	***-17.34****	***-17.81****	***-18.60****	***-17.35****
		(-8.11)	***(-5.07)***	***(-5.01)***	***(-5.53)***	***(-5.19)***	***(-5.30)***	***(-5.13)***	***(-6.56)***	***(-6.75)***	***(-7.23)***	***(-6.32)***
	Adj R^2	43.66%	23.37%	25.12%	29.41%	25.40%	29.21%	27.38%	25.37%	26.47%	29.49%	25.80%
	F	57.58	23.26	25.49	31.41	25.85	31.12	28.52	25.81	27.28	31.54	26.39
EBETA	Cst	13.14***	17.20***	16.99***	18.35***	17.95***	17.31***	17.00***	15.07***	14.37***	15.81***	15.29***
		(4.84)	(4.51)	(4.55)	(5.02)	(5.04)	(4.57)	(4.70)	(3.98)	(3.99)	(3.78)	(3.84)
	Ind. Var.	***-11.75****	***-14.72****	***-14.53****	***-15.73****	***-15.32****	***-15.01****	***-14.78****	***-13.24****	***-12.64****	***-13.77****	***-13.35****
		(-5.02)	***(-4.57)***	***(-4.56)***	***(-5.03)***	***(-5.10)***	***(-4.58)***	***(-4.73)***	***(-3.96)***	***(-3.97)***	***(-3.75)***	***(-3.79)***
	Adj R^2	22.83%	27.03%	26.08%	32.85%	30.15%	26.67%	24.93%	22.31%	20.33%	25.41%	23.24%
	F	22.60	28.04	26.75	36.71	32.50	27.54	25.24	21.96	19.62	25.87	23.10
CR	Cst	1.24	2.46**	2.41**	2.48***	2.54***	2.32***	2.10**	1.59	1.58	1.76	1.70
		(1.28)	(2.48)	(2.46)	(2.73)	(2.90)	(2.64)	(2.34)	(1.10)	(1.05)	(1.39)	(1.16)
	Ind. Var.	***-19.71****	***-34.28****	***-32.43****	***-32.78****	***-34.12****	***-27.96****	***-26.46****	***-21.78****	***-21.25****	***-22.83****	***-22.21****
		(-5.75)	***(-4.20)***	***(-4.40)***	***(-5.25)***	***(-5.15)***	***(-3.96)***	***(-3.78)***	***(-3.84)***	***(-3.33)***	***(-4.45)***	***(-3.84)***
	Adj R^2	25.12%	20.28%	18.29%	23.33%	22.69%	23.33%	20.60%	16.72%	15.30%	18.96%	16.98%
	F	25.48	19.57	17.34	23.21	22.42	23.21	19.94	15.66	14.18	18.08	15.93
	Dependent Variable	Employment (TNPG)										
	Ind. Var.	Raw SBR	SBR^{alpha}_{OTMC}	SBR^{alpha}_{ITMC}	SBR^{alpha}_{OTMP}	SBR^{alpha}_{ITMP}	$SBR^{alpha}_{SUM,OTM}$	$SBR^{alpha}_{SUM,ITM}$	$SBR^{AMB\_BI}_{OTMC}$	$SBR^{AMB\_BI}_{ITMC}$	$SBR^{AMB\_BI}_{OTMP}$	$SBR^{AMB\_BI}_{ITMP}$
DR	Cst	2.19***	2.55***	2.57***	2.55***	2.55***	2.53***	2.54***	2.63***	2.65***	2.60***	2.65***
		(9.10)	(12.45)	(13.04)	(15.93)	(13.21)	(14.33)	(13.14)	(14.30)	(15.33)	(14.69)	(14.09)
	Ind. Var.	***-5.38****	***-6.87****	***-6.94****	***-6.95****	***-6.80****	***-6.44****	***-6.48****	***-6.82****	***-6.89****	***-6.83****	***-6.79****
		(-7.51)	***(-10.57)***	***(-11.02)***	***(-17.26)***	***(-12.16)***	***(-13.94)***	***(-12.44)***	***(-19.37)***	***(-23.22)***	***(-25.82)***	***(-18.33)***
	Adj R^2	77.41%	76.36%	76.92%	80.02%	78.89%	79.55%	78.52%	79.82%	80.27%	80.37%	80.20%
	F	251.22	236.83	244.33	293.39	273.80	284.97	267.92	289.66	297.99	299.94	296.61
EBETA	Cst	4.85***	7.29***	7.31***	7.09***	7.22***	7.30***	7.40***	6.50***	6.51***	6.43***	6.38***
		(4.93)	(12.31)	(12.23)	(14.09)	(15.11)	(10.62)	(11.49)	(12.99)	(13.22)	(14.73)	(15.17)
	Ind. Var.	***-3.67****	***-5.52****	***-5.52****	***-5.40****	***-5.47****	***-5.60****	***-5.68****	***-4.97****	***-4.96****	***-4.89****	***-4.84****
		(-4.10)	***(-10.93)***	***(-10.84)***	***(-11.82)***	***(-13.36)***	***(-9.09)***	***(-10.08)***	***(-10.22)***	***(-10.26)***	***(-11.39)***	***(-11.86)***
	Adj R^2	44.94%	76.91%	76.26%	77.60%	77.33%	75.09%	74.83%	64.09%	64.14%	64.89%	62.18%
	F	60.59	244.14	235.56	253.88	250.04	221.08	218.05	131.27	131.54	135.90	121.02
CR	Cst	1.11***	1.79***	1.89***	1.79***	1.76***	1.58***	1.53***	1.40***	1.49***	1.48***	1.44***
		(3.50)	(9.05)	(9.21)	(9.68)	(8.79)	(6.75)	(6.22)	(4.24)	(4.50)	(4.73)	(4.34)
	Ind. Var.	***-5.99****	***-12.99****	***-13.28****	***-12.42****	***-12.48****	***-9.51****	***-9.21****	***-7.87****	***-8.32****	***-8.36****	***-8.05****
		(-8.04)	***(-6.62)***	***(-7.33)***	***(-11.47)***	***(-8.22)***	***(-5.34)***	***(-5.06)***	***(-6.96)***	***(-6.49)***	***(-7.00)***	***(-6.79)***
	Adj R^2	46.64%	59.65%	63.35%	68.16%	61.84%	54.73%	50.90%	45.03%	48.83%	52.08%	45.90%
	F	64.80	108.94	127.17	157.28	119.31	89.27	76.68	60.81	70.66	80.33	62.93
	Dependent Variable	Economic Performance (CFNAI)										
	Ind. Var.	Raw SBR	SBR^{alpha}_{OTMC}	SBR^{alpha}_{ITMC}	SBR^{alpha}_{OTMP}	SBR^{alpha}_{ITMP}	$SBR^{alpha}_{SUM,OTM}$	$SBR^{alpha}_{SUM,ITM}$	$SBR^{AMB\_BI}_{OTMC}$	$SBR^{AMB\_BI}_{ITMC}$	$SBR^{AMB\_BI}_{OTMP}$	$SBR^{AMB\_BI}_{ITMP}$
DR	Cst	0.58***	0.67***	0.69***	0.69***	0.67***	0.69***	0.68***	0.71***	0.73***	0.71***	0.71***
		(6.90)	(5.18)	(5.49)	(6.61)	(5.44)	(6.39)	(5.69)	(6.52)	(6.91)	(7.65)	(6.40)
	Ind. Var.	***-2.72****	***-3.19****	***-3.26****	***-3.29****	***-3.15****	***-3.06****	***-3.06****	***-3.19****	***-3.24****	***-3.23****	***-3.15****
		(-11.92)	***(-7.22)***	***(-7.44)***	***(-9.80)***	***(-7.67)***	***(-8.70)***	***(-7.78)***	***(-10.44)***	***(-11.47)***	***(-14.02)***	***(-9.69)***
	Adj R^2	81.44%	67.73%	69.73%	73.65%	69.64%	74.05%	71.94%	71.60%	72.89%	73.78%	70.82%
	F	321.30	154.19	169.16	205.07	168.44	209.30	188.13	185.04	197.28	206.46	178.16
EBETA	Cst	1.89***	2.89***	2.87***	2.88***	2.91***	2.93***	2.94***	2.51***	2.47***	2.48***	2.46***
		(5.93)	(6.88)	(6.94)	(9.55)	(8.54)	(8.16)	(7.93)	(6.77)	(7.04)	(7.81)	(7.13)
	Ind. Var.	***-1.83****	***-2.58****	***-2.56****	***-2.59****	***-2.60****	***-2.65****	***-2.65****	***-2.31****	***-2.27****	***-2.28****	***-2.26****
		(-6.18)	***(-7.16)***	***(-7.18)***	***(-9.81)***	***(-8.90)***	***(-8.22)***	***(-8.12)***	***(-6.95)***	***(-7.13)***	***(-7.92)***	***(-7.36)***
	Adj R^2	45.79%	69.13%	67.47%	73.55%	71.70%	69.08%	67.15%	56.92%	55.18%	58.07%	55.49%
	F	62.66	164.47	152.37	203.95	185.93	164.07	150.23	97.43	90.86	102.11	92.02
CR	Cst	0.03	0.35***	0.38***	0.34***	0.34***	0.26***	0.24***	0.17	0.20	0.20	0.19
		(0.23)	(4.43)	(4.71)	(4.33)	(4.67)	(3.07)	(2.63)	(1.07)	(1.25)	(1.41)	(1.22)
	Ind. Var.	***-3.02****	***-6.33****	***-6.33****	***-5.93****	***-6.13****	***-4.75****	***-4.59****	***-3.88****	***-4.00****	***-4.06****	***-3.99****
		(-8.48)	***(-8.12)***	***(-8.35)***	***(-11.32)***	***(-10.41)***	***(-6.65)***	***(-6.34)***	***(-7.92)***	***(-6.89)***	***(-8.18)***	***(-7.74)***
	Adj R^2	48.79%	58.34%	59.17%	63.88%	61.35%	56.24%	52.08%	45.08%	46.27%	50.53%	46.35%
	F	70.55	103.22	106.81	130.10	116.89	94.84	80.33	60.91	63.86	75.56	64.06

Newey-West t-statistics in parentheses; ***p < 0.01, **p < 0.05, * p < 0.1

Table S5 - Systemic banking risk and economic activity under CU (GMM estimation)

The table shows GMM estimation results of economic activity on systemic banking risk using *AMB* and *SKEW* as instruments. CUG stands for capacity utilization growth (production). TNPG denotes total non-farm payroll growth (employment) and CFNAI is the Chicago Fed National Activity Index (economic performance). DR, EBETA, CR, SBR^{CU}call, SBR^{CU}put and SBR^{CU}_{SUMDEV} are as defined before. Standard errors are heteroskedasticity and autocorrelation consistent (HAC) based on Newey and West (1987).

	Dependent Variable	Production (CUG)						Employment (TNPG)						Economic Performance (CFNAI)					
	Ind. Var.	SBR^{CU}_{OTMC}	SBR^{CU}_{ITMC}	SBR^{CU}_{OTMP}	SBR^{CU}_{ITMP}	$SBR^{CU}_{SUMDEV,OTM}$	$SBR^{CU}_{SUMDEV,ITM}$	SBR^{CU}_{OTMC}	SBR^{CU}_{ITMC}	SBR^{CU}_{OTMP}	SBR^{CU}_{ITMP}	$SBR^{CU}_{SUMDEV,OTM}$	$SBR^{CU}_{SUMDEV,ITM}$	SBR^{CU}_{OTMC}	SBR^{CU}_{ITMC}	SBR^{CU}_{OTMP}	SBR^{CU}_{ITMP}	$SBR^{CU}_{SUMDEV,OTM}$	$SBR^{CU}_{SUMDEV,ITM}$
DR	Cst	4.29***	4.38***	4.11***	4.20***	4.32***	4.38***	2.18***	2.25***	2.43***	2.38***	2.19***	2.33***	0.64***	0.62***	0.62***	0.61***	0.60***	0.64***
		(2.90)	(3.08)	(2.96)	(3.43)	(3.33)	(3.55)	(9.43)	(8.50)	(7.42)	(10.18)	(8.57)	(9.77)	(6.80)	(6.03)	(4.93)	(6.21)	(5.98)	(6.82)
	Ind. Var.	***-16.28****	***-16.54****	***-15.79****	***-16.05****	***-16.37****	***-16.52****	***-5.48****	***-5.65****	***-6.15****	***-6.02****	***-5.52****	***-5.89****	***-2.91****	***-2.84****	***-2.84****	***-2.82****	***-2.80****	***-2.89****
		(-4.82)	***(-5.00)***	***(-5.03)***	***(-5.90)***	***(-5.76)***	***(-6.13)***	***(-6.83)***	***(-6.64)***	***(-5.58)***	***(-7.31)***	***(-6.69)***	***(-7.41)***	***(-9.69)***	***(-9.14)***	***(-7.57)***	***(-9.94)***	***(-9.05)***	***(-10.15)***
EBETA	Cst	13.66***	13.50***	13.54***	14.62***	14.34***	15.07***	5.55***	5.53***	6.26***	6.48***	5.75***	6.33***	2.36***	2.22***	2.35***	2.49***	2.36***	2.55***
		(2.79)	(2.88)	(4.09)	(3.24)	(3.54)	(3.13)	(4.95)	(4.81)	(5.22)	(5.10)	(4.65)	(4.66)	(4.38)	(4.04)	(4.60)	(4.19)	(4.00)	(3.89)
	Ind. Var.	***-12.07****	***-11.95****	***-11.98****	***-12.83****	***-12.61****	***-13.18****	***-4.23****	***-4.22****	***-4.79****	***-4.96****	***-4.39****	***-4.84****	***-2.19****	***-2.08****	***-2.19****	***-2.29****	***-2.19****	***-2.34****
		(-2.92)	***(-2.95)***	***(-4.18)***	***(-3.30)***	***(-3.61)***	***(-3.18)***	***(-3.95)***	***(-3.88)***	***(-4.29)***	***(-4.19)***	***(-3.80)***	***(-3.86)***	***(-4.36)***	***(-4.05)***	***(-4.55)***	***(-4.19)***	***(-4.02)***	***(-3.92)***
CR	Cst	2.66**	2.85**	2.68**	2.74**	2.76**	2.80**	1.57***	1.66***	1.83***	1.79***	1.62***	1.73***	0.34***	0.34**	0.35**	0.34**	0.32**	0.35**
		(2.23)	(2.33)	(1.97)	(2.31)	(2.11)	(2.33)	(6.34)	(5.53)	(5.98)	(5.66)	(5.64)	(5.49)	(2.76)	(2.41)	(2.51)	(2.37)	(2.26)	(2.39)
	Ind. Var.	***-30.17****	***-31.45****	***-30.27****	***-30.68****	***-30.86****	***-31.15****	***-9.69****	***-10.31****	***-11.49****	***-11.24****	***-10.08****	***-10.84****	***-5.29****	***-5.30****	***-5.37****	***-5.33****	***-5.21****	***-5.39****
		(-3.42)	***(-3.41)***	***(-2.68)***	***(-3.31)***	***(-2.91)***	***(-3.27)***	***(-3.42)***	***(-3.30)***	***(-3.21)***	***(-3.08)***	***(-3.26)***	***(-3.05)***	***(-3.90)***	***(-3.81)***	***(-3.51)***	***(-3.53)***	***(-3.51)***	***(-3.45)***

***$p < 0.01$, **$p < 0.05$, * $p < 0.1$